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INTERSTATE AIR POLLUTION STUDY. PHASE II PROJECT REPORT. II. AIR POLLUTANT EMISSION INVENTORY

R. Venezia, et al

Public Health Service
Cincinnati, Ohio

May 1966

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PHASE II PROJECT REPORT

II. AIR POLLUTANT EMISSION INVENTORY

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INTERSTATE AIR POLLUTION STUDY

PHASE II PROJECT REPORT

II. AIR POLLUTANT EMISSION INVENTORY

prepared by

R. Venezia
G. Ozolins

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
U. S. Public Health Service
Division of Air Pollution, Technical Assistance Branch
Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

May 1966

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FOREWORD

The Interstate Air Pollution Study was divided into two phases. Phase I, a general study of the overall air pollution problems in the St. Louis - East St. Louis metropolitan area, was conducted to determine specific activities that would require further study in Phase II of the project. The effort was divided into two phases to provide a logical stopping point in the event that interest and resources for proceeding further might not materialize. The necessary impetus did continue, however, and the Phase II operation was also completed.

The Phase I operation resulted in a detailed report, designed primarily for use of the Executive Committee members and their agencies in making decisions concerning the Phase II project operation. A Phase I summary report was also prepared; it received wide distribution.

Numerous papers, brochures, and reports were prepared during Phase II operation, as were some 18 Memorandums of Information and Instruction concerning the project. All of these documents were drawn upon in the preparation of the Phase II project report. The Phase II project report consists of eight separate volumes under the following titles:

I. Introduction
II. Air Pollutant Emission Inventory
III. Air Quality Measurements
IV. Odors - Results of Surveys
V. Meteorology and Topography
VI. Effects of Air Pollution
VII. Opinion Surveys and Air Quality Statistical Relationships
VIII. Proposal for an Air Resource Management Program.

CONTENTS

INTRODUCTION 1

SUMMARY OF RESULTS 4

FUEL COMBUSTION IN STATIONARY SOURCES 5
- Methodology 13
  - Industrial 14
  - Steam-Electric Utilities 18
  - Residential 18
  - Other 18
- Results 18
  - Industrial 18
  - Steam-Electric Utilities 22
  - Residential 22
  - Other 24

SOLID-WASTE DISPOSAL 26
- Methodology 28
  - Combustible Refuse Generated 28
  - Municipal Incinerators 28
  - Open-Burning Dumps and Sanitary Landfills 29
  - On-Site Incineration 29
  - On-Site Open Burning 29
- Results 29

TRANSPORTATION SOURCES 30
- Methodology 30
  - Road Vehicles 30
  - Aircraft, Railroads, and Vessels 32
- Results 32
  - Road Vehicles 32
  - Aircraft, Railroads, and Vessels 34

INDUSTRIAL PROCESS EMISSIONS 35
- Methodology 35
- Results 35
  - Oil Refineries 35
  - Cement Manufacturing 36
  - Asphaltic Concrete Manufacturing 37
  - Steel Manufacturing 37
  - Foundries 37
  - Grain Handling and Processing 37
  - Coffee Roasting 37
  - Chemical Industry 37
  - Solvent Evaporation 37

REFERENCES 40

APPENDIX - EMISSION FACTORS 41

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II. AIR POLLUTANT EMISSION INVENTORY

INTRODUCTION

Knowledge of sources of air pollution in a community and the quantities of the various pollutants emitted to the air can provide the basic framework for further air conservation activities. Through an emission inventory, information relating to the quantities of the various pollutants released, the relative contribution of pollutants from the different source categories, and the geographical distribution of pollutant emissions within the study area may be obtained. The results of an emission survey may be used effectively in metropolitan planning, pollution abatement activities, sampling programs, and diffusion models for predicting atmospheric levels of pollutants.

An emission inventory was conducted during 1963-1964 as part of the St. Louis - East St. Louis Interstate Air Pollution Study. The Study covered an area of 3,567 square miles and included the City of St. Louis and the six surrounding counties - St. Louis, St. Charles, and Jefferson Counties in Missouri and Madison, St. Clair, and Monroe Counties in Illinois. More than 95 percent of the population and almost all of the industrial activity are located in the 400 square miles of the centrally located urbanized part of the Study area. The pollutant emission data presented can be almost entirely attributed to this urbanized portion of the area. Population density and land-use maps, which provide an excellent index to the areal distribution of most pollutant emissions, are presented in Figures 1 and 2.

The pollutants considered in this survey are those emitted in large quantities from a variety and multitude of sources dispersed throughout the area. Included are aldehydes, carbon monoxide, hydrocarbons, nitrogen oxides (calculated as nitrogen dioxide), sulfur oxides (calculated as sulfur dioxide), particulates, and benzo(a) pyrene (B(a)P). The emissions of other pollutants are generally associated with a specific process or operation and, in general, are not distributed throughout the community.

The sources of air pollution in the Study area may be subdivided into the five following general categories:

1. Fuel combustion in stationary plants.
2. Combustion of refuse material.
3. Fuel combustion in transportation vehicles.
4. Industrial process emissions.
5. Solvent evaporation.

The geographical variations of pollutant emissions within the Study area are delineated by presenting emission data for the City of St. Louis and each of the six

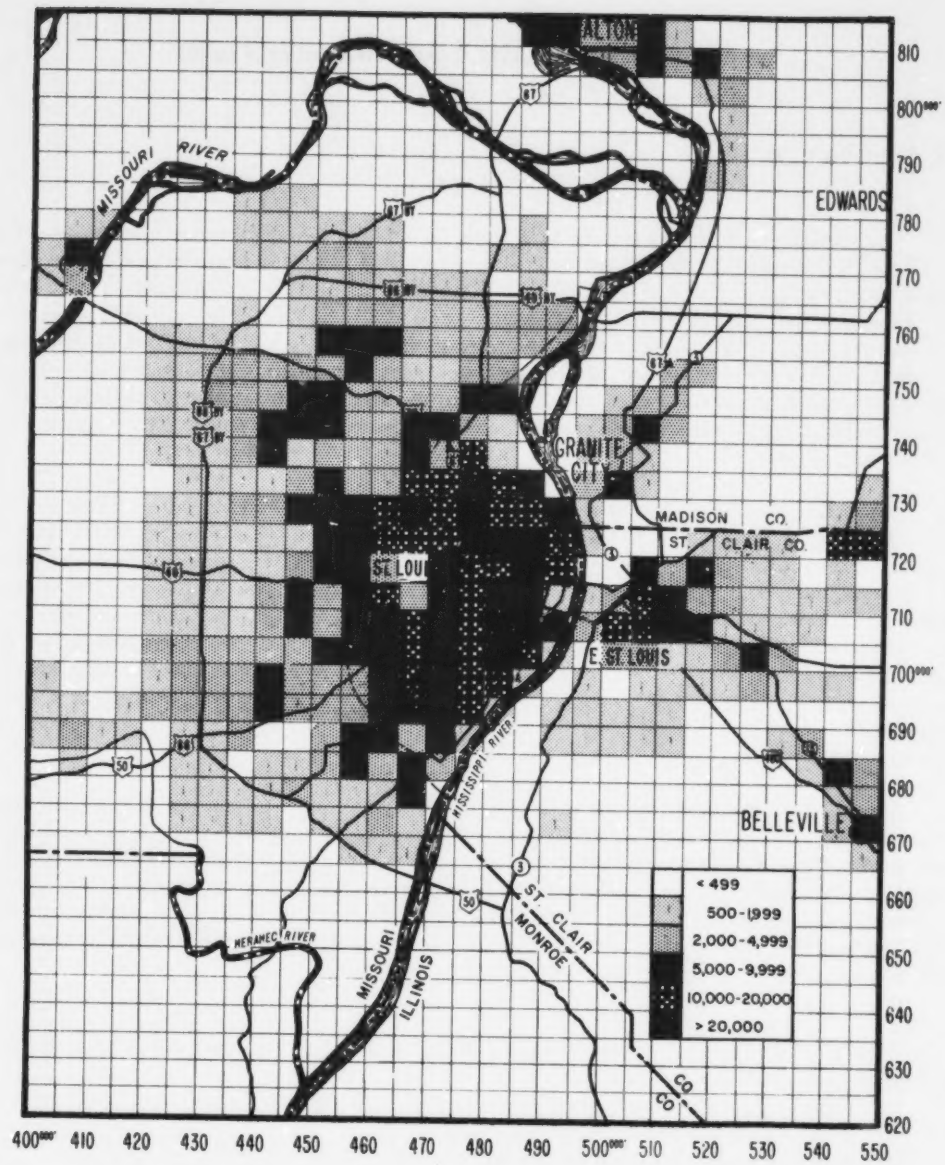

Figure 1. Population by 5,000-foot-square grid cells - 1960 census.

counties individually. In addition, pollutant emissions were designated for 10,000-foot-square grid cells.* Pollutants by grid cells are shown in Figures 3, 4, 9, and 10.

*Grid cells refer to the area north and east of the designated point.

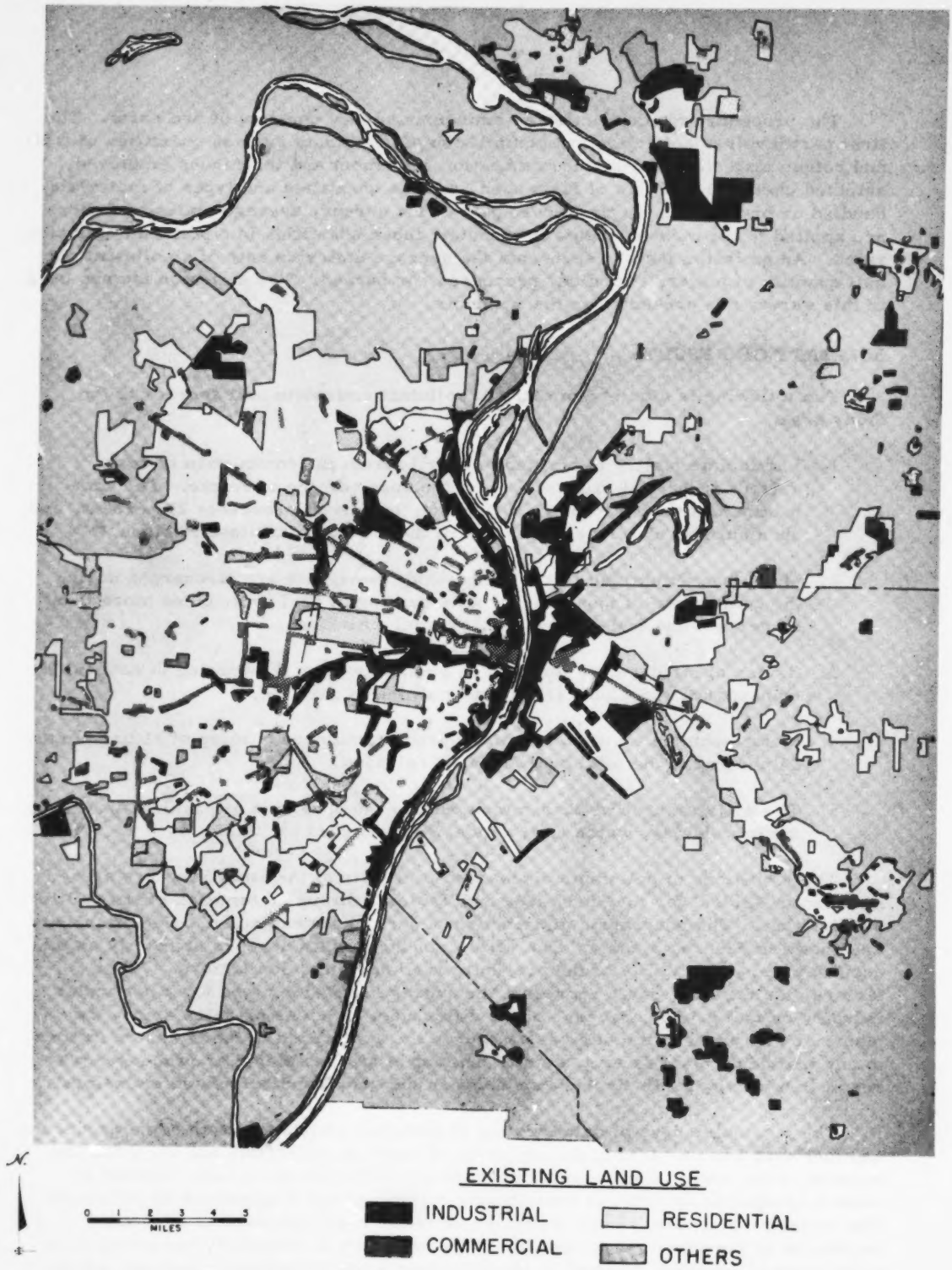

Figure 2. Land use in Metropolitan St. Louis in 1957.

The procedure for conducting an emissions survey consists of two parts. The first part involves collection and compilation of basic data such as quantities of fuels and refuse material burned, the combustion equipment and techniques employed, selected chemical analysis of fuels used, and the quantities and types of materials handled or processed. In the second part of the survey, average emission factors are applied to the measured data to translate these quantities into pollutant emission rates. An emission factor represents the average emission rate of a pollutant per unit quantity of material handled, processed, or burned. The emission factors used in this survey are presented in the Appendix.

SUMMARY OF RESULTS

The following is a brief summary of pollutant emissions and sources in the Study area:

1. Particulate matter is emitted primarily from the combustion of coal, various industrial processes, and the open burning of refuse. The combustion of coal contributes 56 percent, industrial processes 27 percent, and open burning of refuse 10 percent of the total particulate emissions.

2. More than 90 percent of the sulfur oxide emissions are discharged during the combustion of fossil fuels. The burning of coal contributes more than 87 percent and fuel oil 4 percent of total emissions.

3. Oxides of nitrogen are discharged primarily from the burning of coal (51%), transportation sources (35%), and burning of gas (7%).

4. Motor vehicles emit more than 63 percent and open burning of refuse almost 23 percent of the total hydrocarbons released.

5. The major source of carbon monoxide is the operation of gasoline-powered motor vehicles, which emit almost 98 percent of the total.

The emissions of pollutants discharged to the air of the Study area are summarized in Table 1 for the Study area and Tables 2 through 8 for each of the political subdivisions. The geographic distribution of particulate and sulfur oxide emissions are shown in Figures 3 and 4. The validity of the results depends primarily on the accuracy and applicability of the presently available emission factors. These factors, for the most part, represent the average emission rates for a particular industry or fuel group. Because of the differences in emission rates among the plants or fuel users within a given category, the application of the emission factors to any individual plant or even a small number of similar plants or processes may result in a considerable discrepancy between the actual and calculated emissions.

The incompleteness of data relating to pollutant emissions from some processes and fuel uses has resulted in the omission of some air pollutants and air pollution sources in the area. For the most part, these omissions have been confined to source categories or sources contributing relatively small quantities of pollutants. The emission inventory should therefore be fairly representative of total area emissions of the principal pollutants. This inventory of commonly occurring pollutants cannot, however, be used to identify some kinds of pollutant sources, which are few in number but which may cause objectionable neighborhood pollution problems

Table 1. SUMMARY OF AIR POLLUTANT EMISSIONS IN INTERSTATE AIR POLLUTION STUDY AREA, 1963 (tons/year[a])

Source category	Aldehydes	Carbon monoxide	Hydro-carbons	Nitrogen oxides	Sulfur oxides	Partic-ulates	B(a)P[a]
Transportation	1,800	1,088,000	235,000	48,000	4,400	7,100	489
Road vehicles	1,600	1,083,000	231,000	43,400	3,600	4,700	456
Other	200	5,000	4,000	4,700	800	2,400	33
Combustion of fuels stationary sources	600	26,300	6,200	85,200	421,000	86,400	641
Industry	200	2,600	900	22,700	113,000	39,000	427
Steam-electric util.	16	1,000	500	53,200	244,000	22,400	7
Residential	360	19,000	4,000	8,000	50,000	19,000	156
Other	28	3,600	800	1,800	14,000	6,000	51
Refuse disposal	1,300	400	84,700	500	500	15,600	416
Incineration	150	400	400	300	200	1,500	15
Open burning	1,150	na[b]	84,300	200	300	14,100	401
Industrial process emissions	na[b]	na[b]	11,700	4,200	29,600	37,500	na[b]
Solvent evaporation	na[b]	--	36,000	na[b]	--	--	--
Totals	3,700	1,115,000	373,600	137,900	455,000	146,600	1,546

[a]Benzo(a) Pyrene in lb/year.
[b]na = Information not available or not reported.

because of particulates or odors. The maps in Figures 5, 6, and 7, showing location of several types of sources of this kind, are of some assistance in evaluating the potential problems that may be associated with these kinds of sources.

FUEL COMBUSTION IN STATIONARY SOURCES

Coal, fuel oil, and gas are the principal fuels used in the Study area to supply heat and power for industries, steam-electric utilities, households, and commercial establishments. The combustion of these fuels produces various products, which, when released to the air of the community, contribute significantly to the deterioration of the air quality. In fact, these releases constitute the major sources of particulates, oxides of sulfur, and oxides of nitrogen present in the air of the Study area. To more accurately define the sources of pollution and provide better estimates of emissions, the area fuel use was subdivided into the following consumer categories:

1. Industrial
2. Steam-electric utilities
3. Residential
4. Other (commercial, institutional, etc.)

Table 2. SUMMARY OF EMISSIONS IN CITY OF ST. LOUIS, MISSOURI, 1963
(tons/year[a])

Sources	Alde-hydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Partic-ulates	B(a)P[a]
Road vehicles: gasoline	610	436,000	EX[c] 60,000 BB 19,600 TC 14,400	17,200	1,400	1,700	183
Road vehicles: diesel	45	270	750	1,050	150	450	8
Railroads and vessels	55	329	988	1,248	220	604	10
Residential fuel use	117	7,328	1,571	2,727	19,132	7,569	62
Industrial fuel use	23	731	243	5,609	30,529	10,215	60
Fossil fuel steam electric plants	n[d]	45	18	1,773	12,400	1,509	n
Other fuel use	13	2,885	591	980	8,861	3,533	33
Municipal incineration	39	33	33	268	201	1,004	3
Residential incineration	16	na[e]	12	16	n[d]	50	na[e]
Industrial and commercial incineration	63	266	266	22	12	333	7
Open burning (on-site)	158	na[e]	12,320	44	35	2,070	71
Industrial process emissions	na[e]	na[e]	9,447	5	na[e]	2,664	na[e]
Hydrocarbon evaporation[b]	--	--	18,489	--	--	--	--
Totals	1,139	447,887	138,728	30,942	72,940	31,711	437

[a]Benzo(a)Pyrene in lb/year.
[b]Hydrocarbon evaporation includes solvent evaporation and gasoline evaporation from stationary sources.
[c]EX = exhaust, BB = blowby, TC = tank and carburetor.
[d]n = Negligible - less than 0.5 ton/year, or less than 1.0 lb/year.
[e]na = Information or factor not available.

Table 3. SUMMARY OF EMISSIONS IN ST. LOUIS COUNTY, MISSOURI, 1963
(tons/year[a])

Sources	Alde-hydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Partic-ulates	B(a)P[a]
Road vehicles, gasoline	525	380,000	EX[c] 51,400 BB 16,800 TC 12,500	14,400	1,200	1,420	155
Road vehicles, diesel	10	60	140	200	30	90	2
Aircraft: jet, piston, turboprop	28	3,945	719	317	18	214	na[e]
Railroad and vessels	8	54	160	200	36	98	2
Residential fuel use	148	3,234	780	2,523	9,210	3,559	27
Industrial fuel use	19	303	99	3,083	14,887	4,607	13
Fossil fuel steam electric plants	7	620	247	27,853	137,081	5,260	n
Other fuel use	10	126	37	465	2,535	960	8
Industrial and commercial incineration	8	18	18	3	2	37	2
Open burning (on-site)	81	na[e]	6,300	23	18	1,160	37
Residential incineration	9	na[e]	7	9	n[d]	28	na[e]
Industrial process emissions	na[e]	na[e]	1	1,387	8,663	3,835	na[e]
Hydrocarbon evaporation[b]	--	--	9,288	--	--	--	--
Totals	780	388,360	98,496	50,463	173,680	21,268	246

[a]Benzo(a)Pyrene in lb/year.
[b]Hydrocarbon evaporation includes solvent evaporation and gasoline evaporation from stationary sources.
[c]EX = exhaust, BB = blowby, TC = tank and carburetor.
[d]n = Negligible - less than 0.5 ton/year, or less than 1.0 lb/year.
[e]na = Information or factor not available.

Table 4. SUMMARY OF EMISSIONS IN ST. CHARLES COUNTY, MISSOURI, 1963
(tons/year[a])

Sources	Alde-hydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Partic-ulates	B(a)P[a]
Road vehicles: gasoline	39	28,000	EX[c] 3,830 BB 1,250 TC 920	1,100	80	110	12
Road vehicles: diesel	n	3	8	10	2	5	n
Vessels	14	84	253	311	56	154	2
Residential fuel use	10	354	79	197	1,055	384	3
Industrial fuel use	n[d]	1	n[d]	7	44	34	n[d]
Other fuel use	n[d]	n[d]	n[d]	1	n[d]	n[d]	n[d]
Commercial incineration	n[d]	n[d]	n[d]	n[d]	n[d]	n[d]	n[d]
Open burning (on-site)	26	na[e]	1,960	8	6	330	11
Industrial process emissions	na[e]	na[e]	na[e]	na[e]	na[e]	53	na[e]
Hydrocarbon evaporation[b]	--	--	299	--	--	--	--
Totals	89	28,442	8,599	1,634	1,243	1.070	28

[a]Benzo(a)Pyrene in lb/year.
[b]Hydrocarbon evaporation includes solvent evaporation and gasoline evaporation from stationary sources.
[c]EX = exhaust, BB = blowby, TC = tank and carburetor.
[d]n = Negligible - less than 0.5 ton/year, or less than 1.0 lb/year.
[e]na = Information or factor not available.

Table 5. SUMMARY OF EMISSIONS IN JEFFERSON COUNTY, MISSOURI, 1963
(tons/year[a])

Sources	Alde-hydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Partic-ulates	B(a)P[a]
Road vehicles: gasoline	44	31,000	EX[c] 4,280 BB 1,400 TC 1,020	1,200	100	120	13
Road vehicles: diesel	n	3	8	10	2	5	n[d]
Vessels	9	51	154	191	34	94	1
Residential fuel use	11	286	67	219	923	324	2
Industrial fuel use	10	68	20	880	275	840	9
Other fuel use	n[d]	n[d]	n[d]	n[d]	n[d]	n[d]	n[d]
Industrial and commercial incineration	6	25	25	2	1	31	1
Open burning: dumps	110	na[e]	7,695	17	33	1,280	28
Open burning: on-site	16	na[e]	1,260	5	4	210	7
Industrial process emissions	na[e]	na[e]	800	2,475	1,150	8,000	na[e]
Hydrocarbon evaporation[b]	--	--	381	--	--	--	--
Totals	190	31,433	17,110	4,999	2,522	10,904	61

[a]Benzo(a)Pyrene in lb/year.
[b]Hydrocarbon evaporation includes solvent evaporation and gasoline evaporation from stationary sources.
[c]EX = exhaust, BB = blowby, TC = tank and carburetor.
[d]n = Negligible - less than 0.5 ton/year, or less than 1.0 lb/year.
[e]na = Information or factor not available.

Table 6. SUMMARY OF EMISSIONS IN ST. CLAIR COUNTY, ILLINOIS, 1963
(tons/year[a])

Sources	Aldehydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Particulates	B(a)P[a]
Road vehicles: gasoline	146	106,000	EX[c] 14,000 BB 4,600 TC 3,300	4,000	320	390	42
Road vehicles: diesel	3	18	50	70	8	25	1
Railroad and vessels	75	450	1,352	1,668	301	827	13
Residential fuel use	36	4,575	874	1,196	10,783	4,213	35
Industrial fuel use	20	565	189	3,468	23,158	8,618	290
Fossil fuel steam electric plants	1	85	34	3,414	15,988	3,345	n[d]
Other fuel use	2	102	21	239	1,355	615	5
Industrial and commercial incineration	7	16	16	1	1	24	1
Open burning: dumps	371	na[e]	25,934	55	111	4,319	95
Open burning: on-site	150	na[e]	11,500	41	33	1,930	66
Industrial process emissions	na[e]	na[e]	1,500	300	14,368	6,700	na[e]
Hydrocarbon evaporation[b]	--	--	2,183	--	--	--	--
Totals	811	111,811	65,553	14,452	66,426	31,006	548

[a]In lb/year.
[b]Hydrocarbon evaporation includes solvent evaporation and gasoline evaporation from stationary sources.
[c]EX: Exhaust
BB: Blowby
TC: Tank and carburetor
[d]n = Negligible - less than 0.5 tons/year, or less than 1.0 lb/year BaP
[e]na = Information or factor not available.

Table 7. SUMMARY OF EMISSIONS IN MADISON COUNTY, ILLINOIS, 1963
(tons/year[a])

Sources	Alde-hydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Partic-ulates	B(a)P[a]
Road vehicles: gasoline	134	97,000	EX[c] 13,100 BB 4,280 TC 3,220	3,700	300	360	40
Road vehicles: diesel	2	15	40	60	8	25	n[d]
Railroads and vessels	23	144	432	531	96	263	2
Residential fuel use	34	3,083	647	982	8,145	3,177	26
Industrial fuel use	135	956	356	9,653	43,804	14,782	54
Fossil fuel steam electric plants	8	470	189	20,056	79,027	12,330	n
Other fuel use	3	492	101	129	1,248	503	4
Industrial and commercial incineration	2	10	10	1	n[d]	12	n[d]
Open burning: dumps	53	na[e]	3,678	7	19	610	14
Open burning: on-site	140	na[e]	10,500	38	30	1,780	60
Industrial process emissions	na[e]	na[e]	na[e]	na[e]	5,500	16,263	na[e]
Hydrocarbon evaporation[b]	--	--	5,287	--	--	--	--
Totals	534	102,170	41,840	35,157	138,177	50,105	200

[a]Benzo(a)Pyrene in lb/year.
[b]Hydrocarbon evaporation includes solvent evaporation and gasoline evaporation from stationary sources.
[c]EX = exhaust, BB = blowby, TC = tank and carburetor.
[d]n = Negligible - less than 0.5 ton/year, or less than 1.0 lb/year.
[e]na = Information or factor not available.

Table 8. SUMMARY OF EMISSIONS IN MONROE COUNTY, ILLINOIS, 1963
(tons/year[a])

Sources	Alde-hydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Partic-ulates	B(a)P[a]
Road vehicles: gasoline	10	4,600	EX[c] 590 BB 180 TC 150	200	20	20	2
Road vehicles: diesel	n[d]	n[d]	n[d]	n[d]	n[d]	n[d]	n[d]
Vessels	12	70	221	260	47	129	2
Residential fuel use	2	200	42	67	545	208	2
Other fuel use	n[d]	n[d]	n[d]	n[d]	n[d]	n[d]	n[d]
Open burning: dumps	30	na[e]	2,100	5	9	350	4
Open burning: on-site	9	na[e]	780	3	2	117	4
Commercial incineration	n[d]	na[e]	n[d]	n[d]	n[d]	n[d]	n[d]
Hydrocarbon evaporation[b]	--	--	107	--	--	--	--
Totals	63	4,870	4,150	535	623	824	14

[a]Benzo(a)Pyrene in lb/year.
[b]Hydrocarbon evaporation includes solvent evaporation and gasoline evaporation from stationary sources.
[c]EX = exhaust, BB = blowby, TC = tank and carburetor.
[d]n = Negligible - less than 0.5 ton/year, or less than 1.0 lb/year.
[e]na = Information or factor not available.

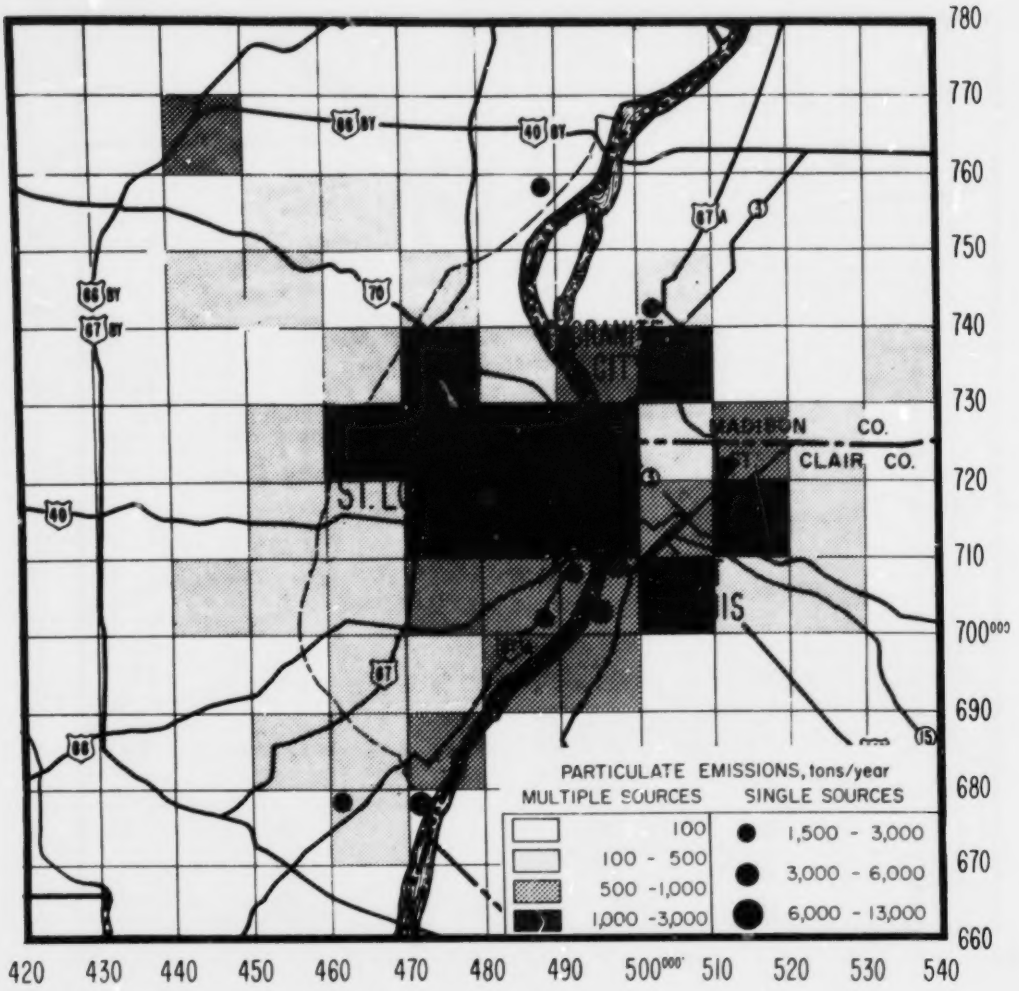

Figure 3. Emissions of particulates in study area.

The emissions of pollutants are not only dependent upon the types and quantities of fuels burned but also on the chemical composition of fuels, firing techniques and equipment employed, and efficiency of air pollution control devices used. Where applicable, these parameters have been considered in the emission calculations.

Methodology

Fuel consumption data for the Study area were obtained through the use of a variety of techniques and from numerous information sources. These varied from individual contact, mostly by questionnaires, to the use of city or metropolitan area totals as reported by the U.S. Bureau of Census or national fuel associations. Where possible, the data have been cross-checked by using different techniques and sources.

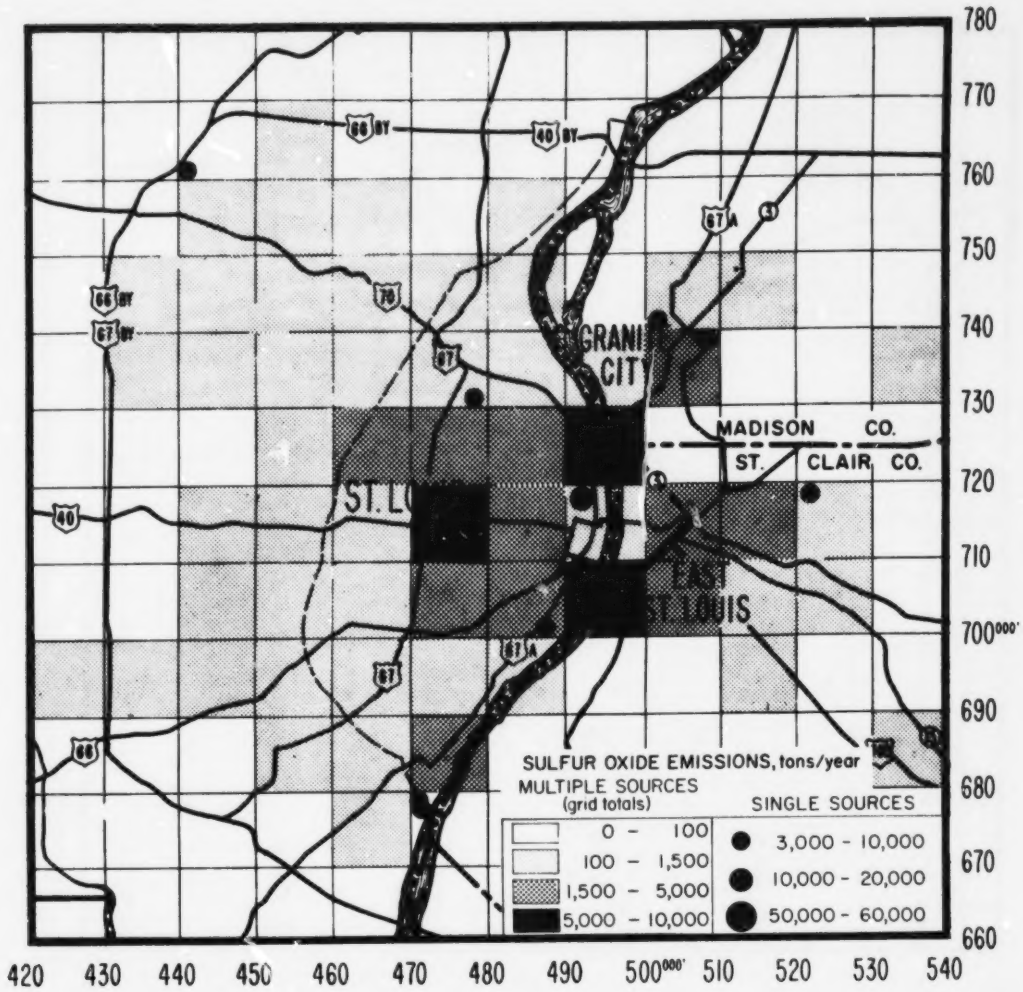

Figure 4. Emissions of sulfur oxides in study area.

Fuel-use data were compiled by consumer categories and by major political subdivisions of the Study area. The techniques used in assessing the fuel consumption of each of the user categories are briefly summarized below.

Industrial - With the cooperation of the Industrial Waste Council and the Metropolitan St. Louis Chamber of Commerce, the largest 900 of the approximately 3,300 manufacturing firms in the Study area were sent questionnaires. Approximately 330 of these establishments returned usable data. Although the percentage of response was small, these firms actually burn a large majority of the fuel consumed in the Study area, especially coal and residual fuel oil, and thus contribute the majority of pollutants from this consumer category. For example, 23 of the 24 largest industrial coal users in the Study area replied to the questionnaire. Most of the firms

not surveyed are engaged in light manufacturing, which requires little fuel for process use, and which generally uses gas or distillate fuel oil to satisfy their space heating requirements.

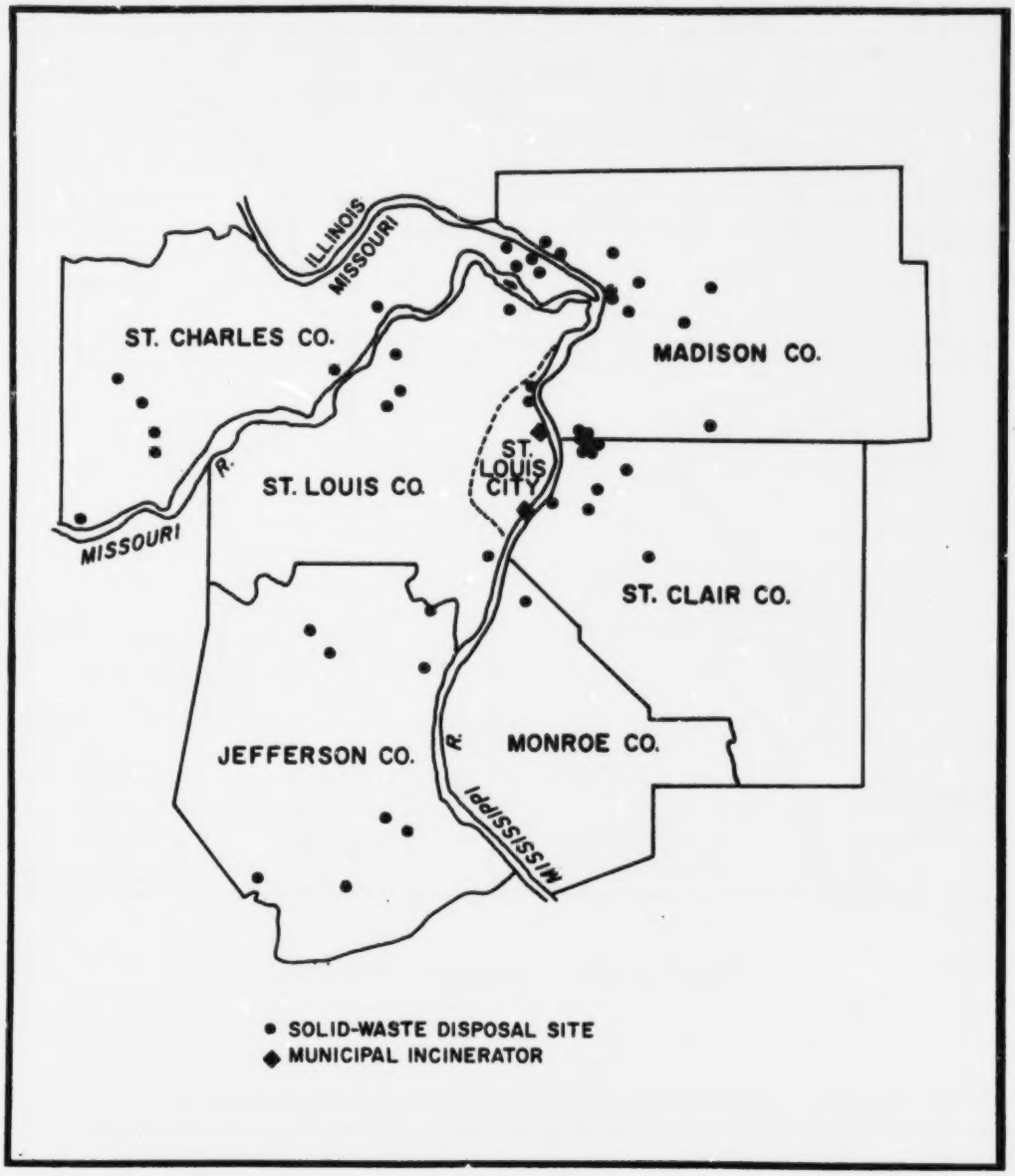

Figure 5. Solid-waste disposal sites and municipal incinerators.

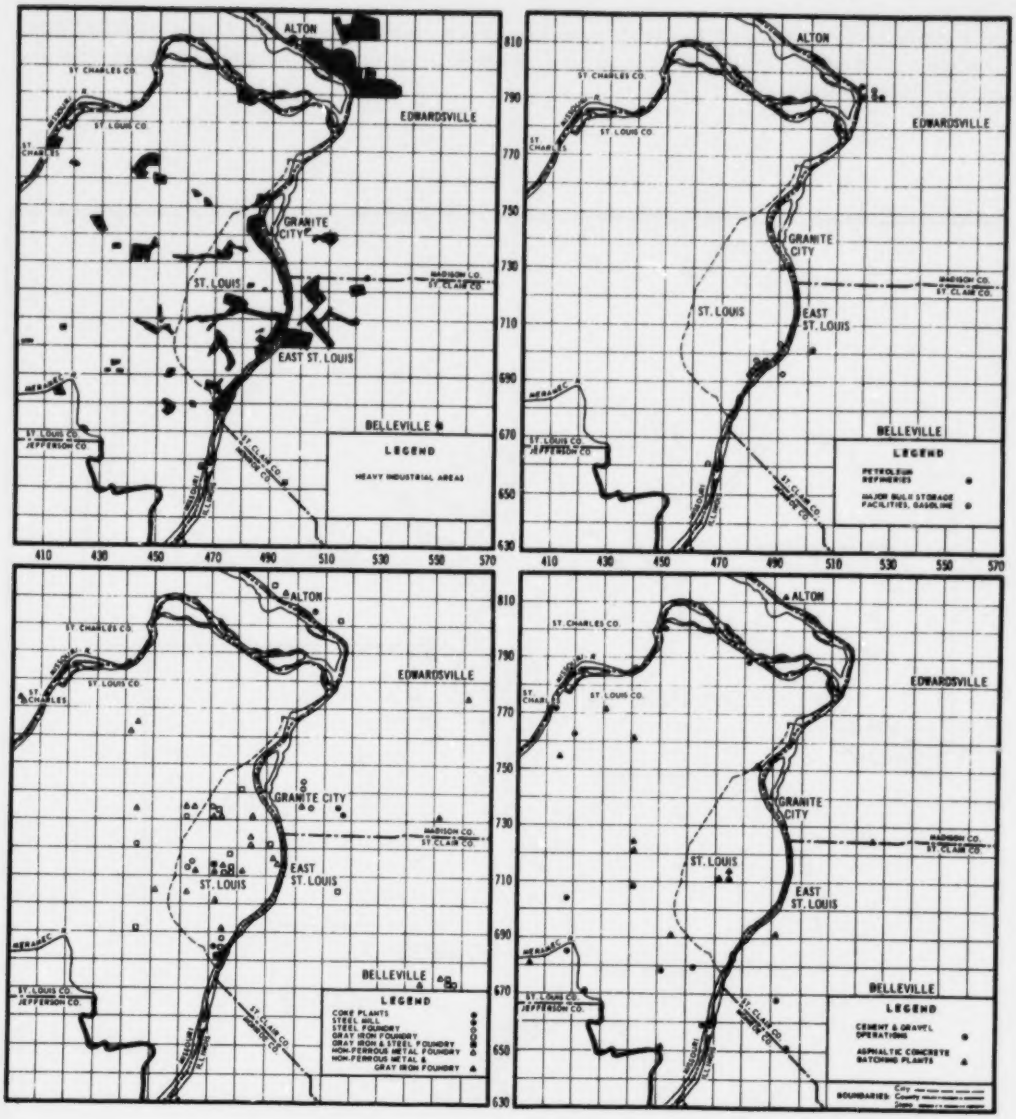

Figure 6. Major industrial operations.

To check the validity of the survey results, the survey data were compared with those reported by the U.S. Bureau of Census for the St. Louis Standard Metropolitan Statistical Area.[1] Industrial coal consumption agreed within 10.5 percent, fuel oil consumption within 7.5 percent, and gas consumption within 37 percent of the amounts reported by the U.S. Bureau of Census. The predominant use of gas in the smaller industrial establishments not surveyed accounts for

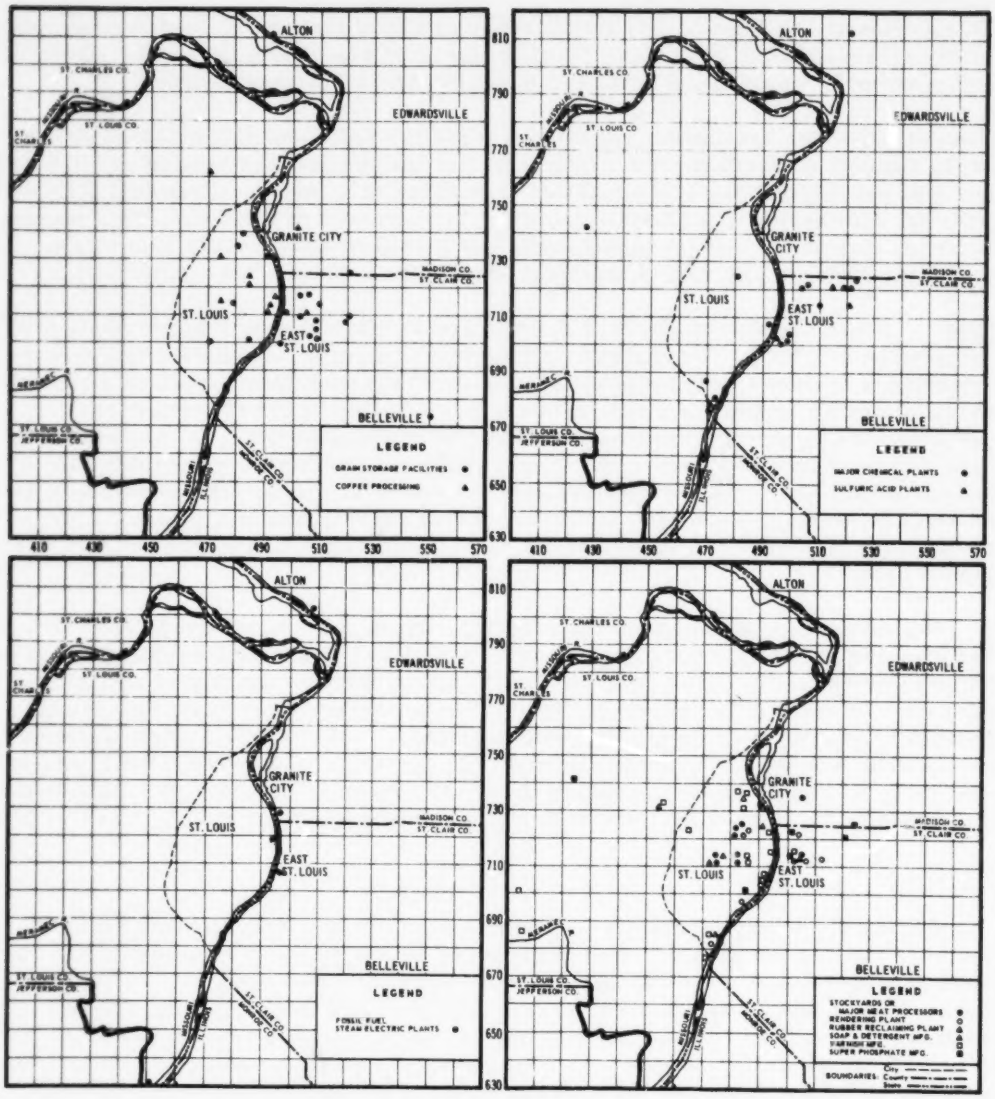

Figure 7. Major industrial operations.

the larger discrepancy in the gas consumption data. Since, however, the combustion of gas produces relatively insignificant amounts of most pollutants, the resulting error may be considered negligible. It is, therefore, estimated that the responses to the questionnaire accounted for more than 90 percent of the area industrial fuel use.

Steam-Electric Utilities - The annual consumption of fuels by each of the five public utility steam-electric generating plants in the area was obtained by questionnaires and verified by information published by the National Coal Association.[2]

Residential - The residential use of the respective fuels was estimated on the basis of the number of dwelling units using each fuel and the average heating requirement per unit per degree-day. The number of dwelling units using a given fuel for each political subdivision was obtained from the U.S. Bureau of Census.[3] This method of estimating domestic fuel consumption has been proved relatively accurate in instances where actual fuel consumption data were available for comparison.

Other - There are more than 12,000 commercial establishments in the Study area. Included in this total, in addition to commercial concerns, are public and private institutions, schools, and hospitals. Questionnaires relating to fuel use and waste disposal practices and one followup letter were mailed to 899 of these concerns; a response of 64 percent was obtained. The 899 establishments were preselected to include businesses and institutions large enough to possibly burn considerable quantities of fuels. Many of the 899 establishments are large office buildings, some of which house as many as 100 individual commercial concerns. The multitude of the smaller concerns and shops did not allow more complete sampling of this consumer category.

On the basis of the information received, the fuel use was extrapolated to include all of the 899 large establishments sampled. The total fuel use by all of the establishments in this consumer category could not be extrapolated in a similar manner. More than 85 percent of the area commercial-institutional fuel use is thought to be consumed by the 899 establishments. This is only a rough approximation and should be interpreted as such. In any event, the presented fuel use data and the resulting pollutant emissions from this consumer category are minor when compared to the total emissions from fuel use in the Study area.

Results

During 1963, approximately 7.5 million tons of coal, 242 million gallons of fuel oil, and 131 billion cubic feet of gas were burned in the Study area. This consumption represents a total heating value of 345×10^{12} Btu per year, of which 52.2 percent was supplied by coal, 40.0 percent by gas, and 7.8 percent by fuel oil. In addition, 1.3 million tons of coal was used in the area for the production of coke.[4] A breakdown of these totals by consumer category and major political jurisdictions is given in Tables 9 and 10. The locations of the 57 largest consumers of fuels - coal, fuel oil and gas - in the area are presented in Figure 8. The quantities of pollutants released in the Study area by the combustion of fuels are summarized in Table 11.

Industrial - During 1963, the manufacturing industry consumed 22 percent of the coal, 47 percent of the fuel oil (mostly residual), and 52 percent of the gas burned in the Study area. The combustion of these fuels resulted in an emission of 39,000 tons of particulates, 113,000 tons of oxides of sulfur, and 23,000 tons of oxides of nitrogen. These emissions accounted for between 20 and 30 percent of the area totals of these pollutants.

The coal consumption of individual plants ranges from a few tons per year to over 250,000 tons annually. A study of the major coal consumers (industrial,

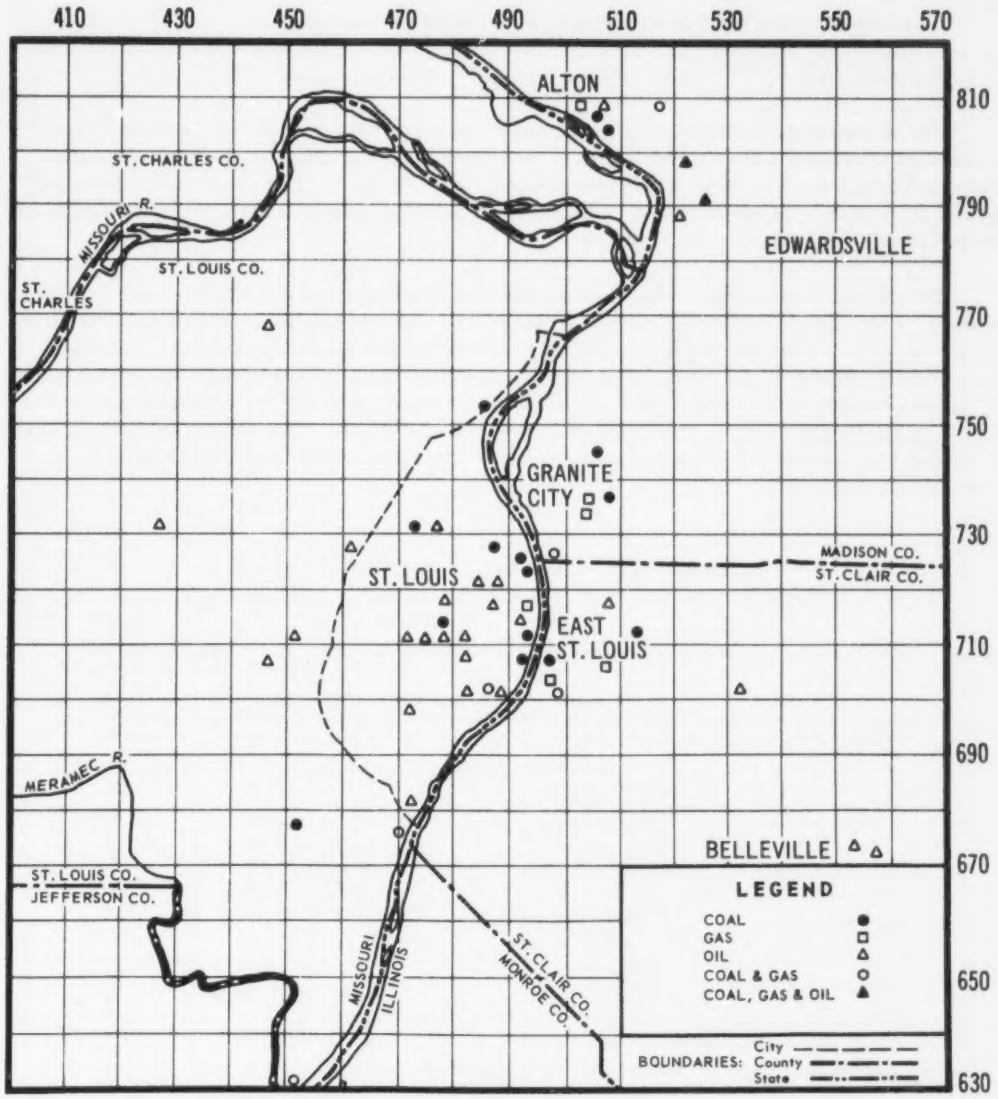

Figure 8. Locations of fuel consumers that use 565 x 10^9 or more Btu per year.

steam-electric utilities, and commercial) in the area conducted by the National Coal Association[4] indicated the following distribution.

50 plants use between 1,000 and 25,000 tons per year

12 plants use between 25,000 and 50,000 tons per year

4 plants use between 50,000 and 100,000 tons per year

8 plants use between 100,000 and 250,000 tons per year

6 plants use 250,000 or more tons per year.

The amounts of particulates released by the combustion of coal are not only dependent upon the quantity and type of coal burned, but also on the firing equipment used and the collection devices employed. Table 12 summarizes industrial coal use by burner type and lists the annual coal consumption according to types of air pollution control devices used.

The quantity of sulfur oxides released are dependent directly upon the sulfur content of the fuels used. The sulfur content of the coal used in the area averages from 1.0 to 3.3 percent with a mean of slightly less than 3.0 percent.[4] Approximately 90 percent of the fuel oil used by industries is residual, with the remaining 10 percent distillate. The sulfur content of distillate fuel oil is approximately 0.3 to 0.7 percent and that of residual of 1.5 to 3.6 percent. The sulfur content of gas is negligible. Selected chemical analyses of the fuels used in the area are summarized in Table 13.

Table 9. ANNUAL FUEL CONSUMPTION IN INTERSTATE AIR POLLUTION STUDY AREA, 1963

Fuel	Consumer category	Annual consumption	Percent of total
Coal, tons/year	Industry[a]	1,628,000	21.8
	Steam-electric utilities	4,874,000	65.3
	Residential	738,000	9.9
	Other	222,000	3.0
	Total	7,462,000	100.0
Fuel oil--residual, gal/year	Industry	106,223,000	99.0
	Steam-electric utilities	642,000	0.5
	Residential	n[b]	n[b]
	Other	n[b]	n[b]
	Total	106,865,000	100.0
Fuel oil--distillate, gal/year	Industry	8,284,000	6.1
	Steam-electric utilities	0	0
	Residential	120,543,000	88.9
	Other	6,414,000	5.0
	Total	135,233,000	100.0
Gas, million cubic feet/year	Industry	68,151	51.8
	Steam-electric utilities	9,252	7.0
	Residential	51,078	38.9
	Other	2,974	2.3
	Total	131,454	100.0

[a]An additional 1,327,000 tons is used in the production of coke.
[b]n = Negligible.

Table 10. ANNUAL FUEL CONSUMPTION IN POLITICAL SUBDIVISIONS OF INTERSTATE AIR POLLUTION STUDY AREA, 1963

Fuel	Jurisdiction	Industry	Steam-electric plants	Residential	Other	Totals
Coal, tons/year	City of St. Louis	474,400	177,300	278,000	140,000	1,069,700
	St. Louis County	191,300	2,473,300	126,500	37,500	2,828,600
	St. Charles County	640	--	13,900	n[a]	14,540
	Jefferson County	40,000	--	11,100	n[a]	51,100
	Madison County	553,300	1,884,300	122,300	19,900	2,579,800
	St. Clair County	368,000	339,500	163,500	24,300	895,300
	Monroe County	n[a]	--	7,900	n[a]	7,900
	Totals	1,627,640	4,874,400	723,000	222,300	7,462,000
Fuel oil, gal/year	City of St. Louis	6,280,000	45,000	30,100,000	3,480,000	39,900,000
	St. Louis County	23,040,000	--	43,900,000	1,670,000	68,610,000
	St. Charles County	60,000	--	5,800,000	20,000	5,880,000
	Jefferson County	380,000	--	7,000,000	3,000	7,380,000
	Madison County	79,230,000	220,000	15,800,000	260,000	95,510,000
	St. Clair County	5,510,000	375,000	16,700,000	770,000	23,360,000
	Monroe County	n[a]	--	1,400,000	n[a]	1,400,000
	Totals	114,510,000	640,000	120,500,000	6,400,000	242,040,000
Gas, million cubic feet/year	City of St. Louis	5,992	536	15,378	1,524	23,430
	St. Louis County	5,986	2,467	18,831	1,172	28,456
	St. Charles County	n[a]	--	638	8	646
	Jefferson County	3,751	--	865	n[a]	4,616
	Madison County	21,346	6,194	3,350	95	30,985
	St. Clair County	5,475	--	3,451	77	9,003
	Monroe County	n[a]	--	172	n[a]	172
	Totals	42,550	9,200	42,685	2,876	97,308

[a]n = Negligible.

Table 11. AIR POLLUTANT EMISSIONS FROM COMBUSTION OF FUELS IN STATIONARY SOURCES IN INTERSTATE AIR POLLUTION STUDY AREA, 1963 (tons/year[a])

Fuel	User category	Aldehydes	B(a)P[a]	Carbon monoxide	Hydro-carbons	Nitrogen oxides	Sulfur oxides	Partic-ulates
Coal	Industrial	3	414	2,442	814	16,276	98,390	37,990
	Steam electric	11	7	1,000	487	51,261	244,443	22,400
	Residential	1	157	18,409	3,682	2,945	46,194	18,409
	Other	n[b]	31	3,567	714	571	13,800	5,550
	Totals	15	609	24,663	5,697	71,053	402,827	84,364
Fuel oil	Industrial	93	10	94	93	2,055	14,300	683
	Steam electric	n[b]	n[b]	n[b]	n[b]	41	31	n[b]
	Residential	113	n[b]	113	113	2,015	3,590	671
	Other	6	1	6	6	103	198	34
	Totals	212	11	213	212	4,214	18,119	1,388
Gas	Industrial	111	2	89	n[b]	5,376	15	423
	Steam electric	4	n[b]	n[b]	n[b]	1,793	3	68
	Residential	244	n[b]	74	244	2,935	9	354
	Other	20	1	5	20	210	n[b]	27
	Totals	379	3	168	264	10,314	27	872
	Grand totals	606	623	25,799	6,173	85,518	420,973	86,624

[a]Benzo(a)Pyrene in lb/year.
[b]n = Negligible.

Steam-Electric Utilities - The steam-electric generating plants are the major coal consumers in the Study area. During 1963, collectively they burned almost 4.9 million tons of coal, which represents 65.3 percent of the coal used in the area. In addition, the steam-electric plants consumed 642,000 gallons of fuel oil (residual) and 9.3 billion cubic feet of gas, or 0.3 and 7 percent, respectively, of the total oil and gas used. The steam-electric utilities emitted 53.6 percent of the oxides of sulfur, 15 percent of the particulates, and 38.5 percent of the oxides of nitrogen released to the air of the Study area from all pollution sources.

Four of the five steam-electric utilities are fully equipped with electrostatic precipitators that range in efficiency from 90 to 98 percent. The remaining installation is equipped with settling chambers and mechanical collectors, with an overall efficiency of approximately 70 percent. In summary, approximately 2.5 million tons of coal is burned in installations of 98 percent collection efficiencies; 1.4 million tons, in installations of 92.5 percent collection efficiencies; 0.5 million tons, in installations of 90 percent collection efficiencies; and 0.5 million tons, in installations of approximately 70 percent collection efficiency.

Residential - Approximately 50 percent of the dwelling units in the Study area use gas as the heating fuel. Coal, distillate fuel oil, and other fuels were used in 22, 21, and 7 percent, of the dwelling units, respectively. Collectively, the residential use of fuels accounted for 39 percent of the gas, 50 percent of the fuel oil, and 10 percent of the coal burned in the Study area.

A considerable area variation in the use of a particular fuel is evident. Natural gas is used in approximately 57 percent of the dwelling units in the Missouri portion,

Table 12. INDUSTRIAL COAL USE BY BURNER TYPE AND TYPE OF AIR POLLUTION CONTROL DEVICES USED IN INTERSTATE AIR POLLUTION STUDY AREA, 1963

Type of firing equipment	Air pollution control devices									
	No control devices		Settling chambers or water sprays		Cyclones or other inertial separators		Multiclones or ESP[b]		Total	
	Number of units[a]	Quantity of coal burned, tons/year	Number of units[a]	Quantity of coal burned, tons/year	Number of units[a]	Quantity of coal burned, tons/year	Number of units[a]	Quantity of coal burned, tons/year	Number of units[a]	Quantity of coal burned, tons/year
Underfeed stokers	13	21,000	5	2,400					18	23,400
Chain grate stokers	24	244,000	11	325,000	7	88,000			42	657,000
Traveling grate stokers	5	5,600	5	135,000	3	23,000			13	163,600
Hand-fired	12	4,000							12	4,000
Pulverized coal units					10	114,000	22	516,000	32	630,000
Spreader stokers with ash reinjection					3	35,000	1	50,000	4	85,000
Spreader stokers without ash reinjection	2	8,000	6	17,000	1	28,000	1	15,000	10	68,000
Totals	56	282,600	27	479,400	24	288,000	24	581,000	131	1,631,000
Percent of total	42.8	17.4	20.6	29.3	18.3	17.7	18.3	35.6	100	100

[a]The number of units given represents the number of boilers, not installations. An installation with two boilers is entered as 2.
[b]Electrostatic precipitators.

Table 13. SELECTED CHEMICAL ANALYSIS OF FUELS IN INTERSTATE AIR POLLUTION STUDY AREA, 1963

Fuel and source	Quantity consumed annually	Selected chemical analysis of fuels[a]			
		Sulfur, %	Ash, %	Volatile, %	Average heating value
Coal	(tons)				(Btu/lb)
Belleville District	5,411,600	3.3	10	36	11,300
Southern Illinois	2,600,000[b]	1.5	8	34	12,200
East Kentucky	450,000[c]	1.0	5	38	13,500
Miscellaneous	250,000	--	--	--	--
Residual fuel oil	(gallons) 106,865,000	1.6[d]	n[e]	100	(Btu/gal) 151,000
Distillate fuel oil	(gallons) 135,233,000	0.4[d]	n[e]	100	(Btu/gal) 142,000
Gas	(10^6 ft^3) 131,454	0.0008	n[e]	100	(Btu/ft^3) 1,050

[a] As-burned basis.
[b] 876,000 tons used for coking.
[c] 450,000 tons used for coking.
[d] Estimated average.
[e] n = Negligible.

but in only 30 percent in the Illinois part; whereas coal is used in 35 percent of dwellings on the Illinois side and only 17 percent in Missouri. A summary of the domestic heating fuels by county and the City of St. Louis is given in Table 14. Emissions of particulates and sulfur oxides from residential uses are shown in Figures 9 and 10.

Other - The commercial-institutional use of fuels is minor when compared to the other consumer categories. Similarly, the pollution load arising from these establishments is relatively small. This consumer category consumed less than 10 percent of any of the fuels used in the area.

On the basis of the returned questionnaires, the following generalizations relating to the use of fuels and types of firing equipment and control devices used may be made. Approximately 29 percent of the establishments use coal as the heating fuel, 16 percent use fuel oil, 45 percent use gas, and 11 percent use various combinations of these fuels. The use of coal is centered primarily in the City of St. Louis, where coal is used in 52 percent of the establishments.

The returned questionnaires indicated that 150 establishments are heating with coal; 135 of these are equipped with underfeed stokers, 8 with chain grate stokers, 3 with spreader stokers, 3 with hand-fired, and 1 with traveling grate. Only 9 of the 150 establishments are equipped with air pollution control devices (7 with settling chambers and 2 with multiple cyclones). The types of firing equipment used and the quantity of coal burned are summarized in Table 15.

Table 14. SUMMARY OF DOMESTIC HEATING BY NUMBER OF DWELLING UNITS[a] IN INTERSTATE AIR POLLUTION STUDY AREA FROM 1960 CENSUS

	Missouri portion				Illinois portion			
	St. Louis City	St. Louis County	St. Charles County	Jefferson County	Madison County	St. Clair County	SMSA	Percent of total
All occupied units	248,651	198,405	14,579	18,580	67,018	77,530	624,763	100.0
Heating fuel								
Utility gas	141,804	125,756	1,569	3,887	20,726	22,520	316,262	50.6
Fuel oil, kerosene, etc.	41,199	44,731	6,387	8,243	18,265	19,714	138,539	22.2
Coal or coke	59,365	19,346	2,300	1,965	21,191	28,986	133,153	21.3
Electricity	533	676	212	83	310	196	2,010	0.3
Bottled, tank, or LP gas	3,891	7,177	3,320	3,188	6,075	5,718	29,369	4.7
Other fuel	1,172	631	791	1,177	429	353	4,553	0.7
None	687	88	--	37	22	43	877	0.2

[a]Taken from Reference 3.

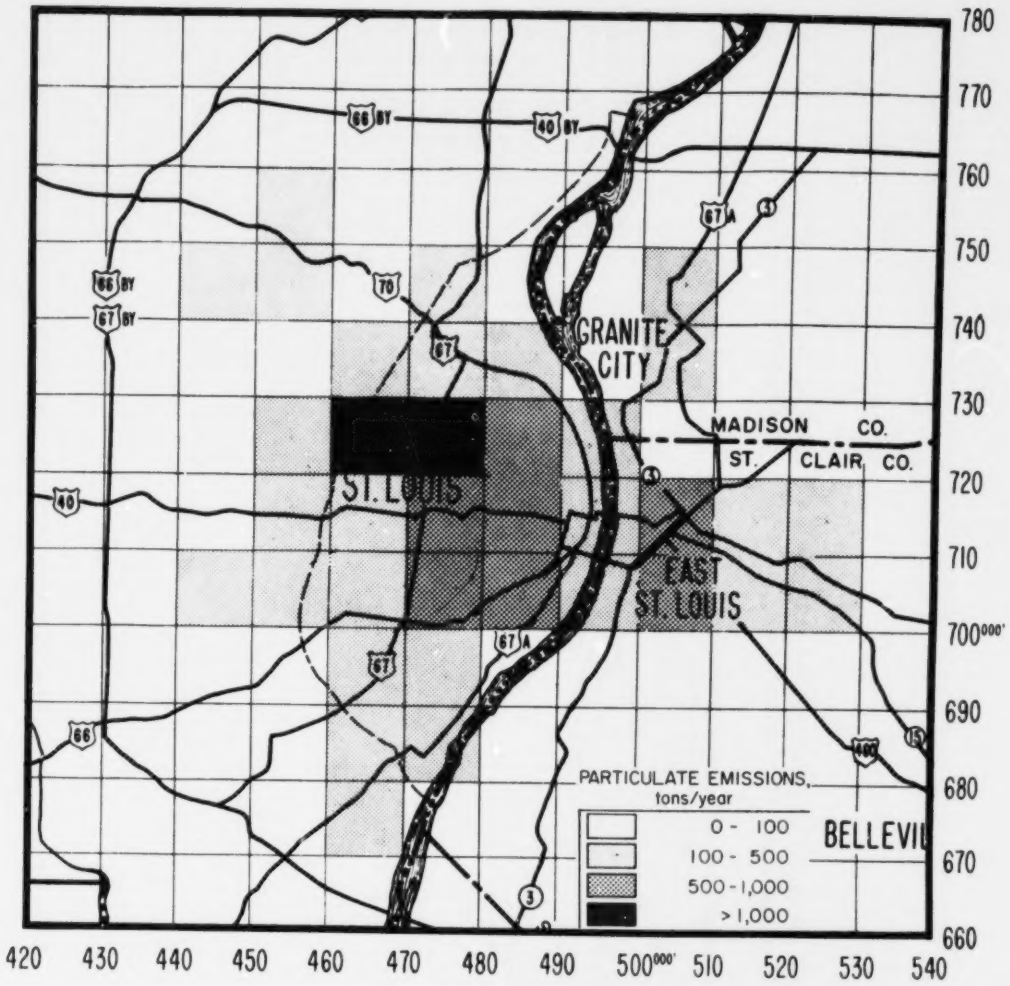

Figure 9. Emissions of particulates from the residential use of fuels.

SOLID WASTE DISPOSAL

Refuse material generated within the Study area is disposed of through municipal and on-site incineration, open-burning dumps, backyard or on-site open burning, sanitary landfills, and salvage operations. (On-site means that the refuse is disposed of on the premises on which it is produced.) A variation of disposal practices among the different political subdivisions within the Study area is clearly evident and is therefore considered in making emission estimates. For example, the City of St. Louis operates two municipal incinerators; St. Louis County operates a sanitary landfill; and the surrounding counties have open-burning dumps scattered throughout the area. In addition to these, on-site incineration and open burning are employed to a varying extent in all of the jurisdictional areas.

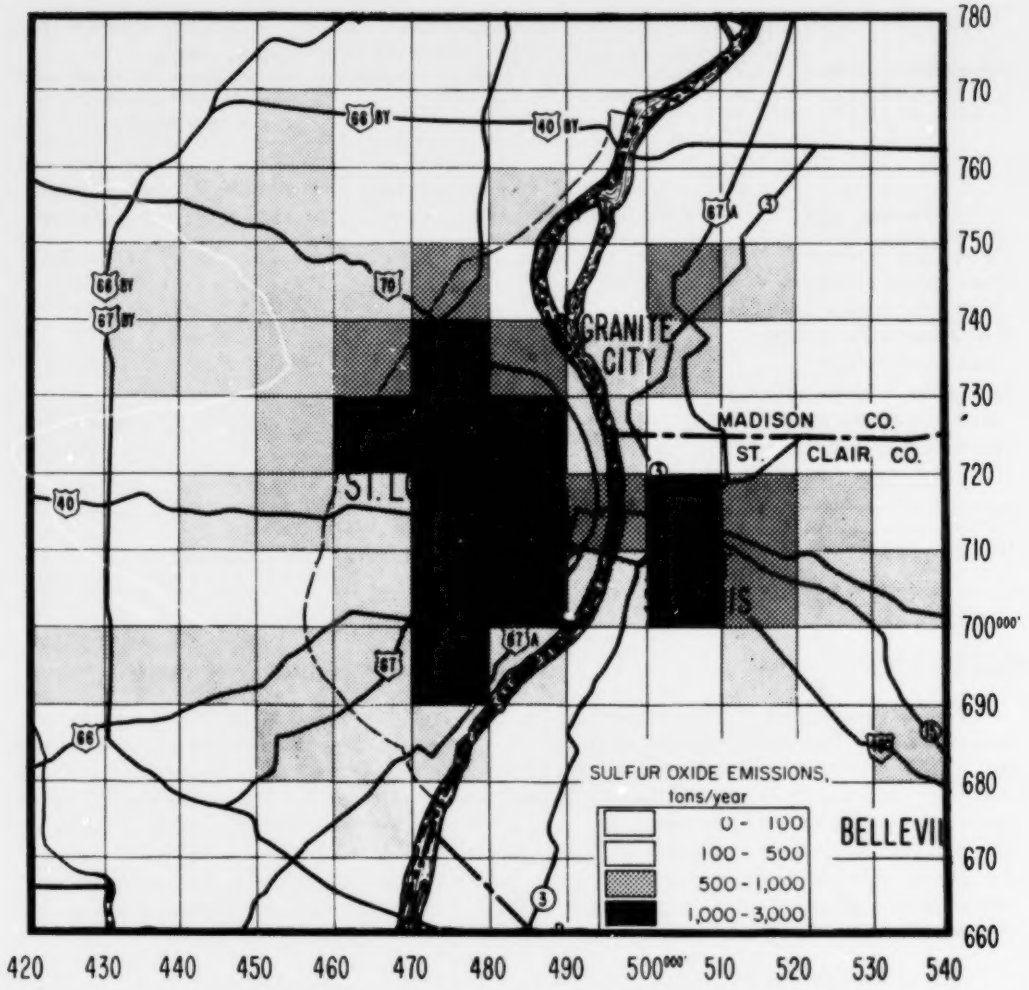

Figure 10. Emissions of sulfur oxides from the residential use of fuels.

To estimate the pollution load released by the combustion of refuse material, the quantities of refuse material incinerated and burned openly had to be determined. This attempt was severely hampered by the lack of authentic and complete data. The available data relating to refuse quantities handled at collective disposal sites ranged from relatively accurate records for the municipal incinerators to "rough" estimates for the landfills and dumps. The only way possible, within the available resources, to estimate the quantities burned on-site was to assume average per capita production of waste material and assume that the difference between the quantity generated and the quantity disposed of at collection sites was that disposed of on-site. Any interpretation of the data should then be viewed within the accuracies and limitations of these estimates.

Table 15. COMMERCIAL-INSTITUTIONAL COAL USE BY BURNER TYPE[a] IN INTERSTATE AIR POLLUTION STUDY AREA, 1963

Burner type	With air pollution control devices		Without air pollution control devices	
	Number of installations[b]	Quantity of coal burned, tons/year	Number of installations	Quantity of coal burned, tons/year
Underfeed stokers	3	326	132	20,082
Chain grate stokers	4	15,629	4	7,747
Traveling grate stokers	-	-	1	30,785
Spreader stoker with ash reinjection	1	2,000	-	-
Spreader stoker without ash reinjection	1	682	1	4,000
Hand-fired units	-	-	3	328
Totals	9	18,637	141	62,492

[a]Unexpanded partial total, based only on returned questionnaires.
[b]The presented numbers refer to installations, not individual boilers.

Methodology

For the purposes of this investigation, it was assumed that the total refuse generated was 4.5 pounds per capita per day (household, commercial and industrial) and that 75 percent, or 3.4 pounds per capita per day, was combustible. These per-capita averages are based on the results of past studies in 12 cities conducted by the American Public Works Association.[7] An average per-capita collection of refuse of approximately 4 pounds per day with a range of 3.0 to over 4.5 pounds per day was observed. Since, however, the amount collected does not include the portions of refuse disposed of on-site, an estimate higher than 4 pounds per capita per day is likely.

The variations among the sectors of the Study area in the per capita generation of combustible waste are assumed to be negligible; therefore 3.4 pounds per capita per day seems reasonable for all sectors of the Study area. The amount of commercial and industrial refuse undoubtedly decreases in the predominately residential counties of the area; however, an increase in yard and garden rubbish in residential areas would tend to minimize the variation.

Combustible Refuse Generated - The quantity of combustible refuse generated in each area is based on the estimated 1963 population and 3.4 pounds per capita per day. The per capita average of 3.4 pounds per day compares favorably with the 3.1 pounds per day reported for St. Louis County by Horner and Shifrin.[8] Since the 3.1 pounds per day was based on the amount collected, a total production of more than 3.1 is likely.

Municipal Incinerators - Data relating to the quantities of refuse material burned at the two St. Louis municipal incinerators was supplied by the City of St. Louis.

Open-Burning Dumps and Sanitary Landfills - The quantities of refuse brought to the dumps and landfills are based on estimates obtained in cooperation with the Illinois and Missouri Health Departments. Since actual weights were unavailable, estimates were generally based on the number of loads brought in per day and an estimate of the weight of refuse in the average load.

On-Site Incineration - The quantity of refuse disposed of by on-site incineration at major commercial and industrial establishments was supplied in the questionnaires and expanded to include the establishments not responding. The quantity of refuse disposed of in domestic incinerators was based on the number of gas-fired incinerators in use and an estimated quantity burned per unit. Since, however, information on the number of domestic incinerators in use was available only for the City of St. Louis and St. Louis County, the estimated quantities disposed of in residential incinerators are undoubtedly low.

On-Site Open Burning - The difference between the amount of waste generated and that disposed by the above mentioned means in each of the political subdivisions was assumed to be burned on-site.

Results

An estimated 1,329,000 tons of combustible refuse material is generated annually in the Study area. A breakdown of this total by county and the City of St. Louis individually is given in Table 16. Table 16 also presents the quantities of refuse material disposed of by the various disposal methods in each political subdivision. In some instances refuse material is transported from one jurisdictional area to others for disposal. Where possible this transfer has been taken into account. For this reason the quantities given in Table 16 may show more refuse disposed of than generated in a given county. The predominant direction of refuse material transfer was from the City of St. Louis and St. Louis County to the counties on the Illinois side of the river.

An estimated 948,000 tons, or 70 percent, of the total refuse generated is disposed of at collection sites, with the remainder being burned on-site. The locations of the collection disposal sites are shown in Figure 5.

Table 16. REFUSE DISPOSAL IN INTERSTATE AIR POLLUTION STUDY AREA, 1963 (tons/year)

Political subdivision	Combustible refuse generated	Incineration		Landfills	Open burning	
		Municipal	On-site		Dumps	On-site
St. Louis City, Missouri	440,000	223,000	44,000	100,000	--	88,000
St. Louis County, Missouri	480,000	--	13,000	296,000	--	45,000
St. Charles County, Missouri	40,000	--	100	26,000	--	14,000
Jefferson County, Missouri	50,000	--	2,500	19,000	55,000	9,000
Madison County, Illinois	145,000	--	1,000	n[a]	29,000	75,000
St. Clair County, Illinois	165,000	--	2,000	n[a]	185,000	82,000
Monroe County, Illinois	9,000	--	n[a]	n[a]	15,000	5,000
Totals	1,329,000	223,000	62,600	441,000	284,000	318,000

[a]n = Negligible.

On-site open burning is used for the disposal of approximately 25 percent of the total refuse generated in the area. Included in this total, however, are the commercial and industrial on-site incinerators not shown on the questionnaires, and the residential non-gas-fired incinerators. Similarly, since this total was obtained by difference, any errors in the assumed per capita generation or in the quantities handled at the collective disposal sites will be reflected in these figures. In addition, since the quantity of refuse transported from the City of St. Louis to areas outside could not be estimated accurately, the on-site open burning may be subject to considerable error.

The quantities of air pollutants released during the burning of refuse material are shown in Table 17. Since the landfills in the area burn only intermittently, no pollution load is ascribed to this method of refuse disposal. The pollutants generated by refuse burning are primarily hydrocarbons and particulates. Approximately 85,000 tons of hydrocarbons and 15,000 tons of particulates are released annually from this source category. Open burning, on-site or at dumps, accounts for more than 90 percent of these pollutants from this source category.

Table 17. AIR POLLUTANT EMISSIONS FROM SOLID-WASTE DISPOSAL IN INTERSTATE AIR POLLUTION STUDY AREA, 1963 (tons/year[a])

Category	Aldehydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Particulates	B(a)P[a]
Incineration	150	377	396	323	226	1,486	14
Municipal	39	33	33	268	201	1,004	3
Residential	25	na[b]	19	25	25	80	na[b]
Industrial	52	208	208	17	na[b]	262	6
Other	34	136	136	13	n[c]	140	5
Open burning	1,140	na[b]	84,300	165	297	14,147	402
On-site	572	na[b]	44,500	80	127	7,473	245
Dumps	568	na[b]	39,800	85	170	6,674	157
Total	1,290	377	84,696	488	523	15,633	416

[a]Benzo (a) Pyrene in lb/year.
[b]na = Information not available or not reported.
[c]n = Negligible.

TRANSPORTATION SOURCES

The transportation sources of air pollution include any vehicles that are powered by the combustion of fuels. Road vehicles (automobiles, buses, and trucks) are by far the most important community-wide transportation source of air pollution. Other transportation sources include railroads, aircraft, and river vessels.

Methodology

Road Vehicles - The quantity of gasoline and diesel fuel consumed in a community is an index to the amounts of the various pollutants released to the air of the community from the operation of automobiles, buses, and trucks.

The quantity of gasoline sold in a metropolitan area is approximately the same as the amount consumed in the area. For the purposes of this investigation, gasoline sales in the Study area, less evaporation and other losses, are considered to equal the amount burned. The effect of through traffic, i.e., the purchase of gasoline outside the area and its consumption inside and vice versa, is considered insignificant when compared to the total gasoline consumption in the area. Since the service boundaries of the gasoline distributors do not coincide with those of the Study area, gasoline sales data for the entire Study area could not be obtained directly. Actual gasoline sales, in gallons, were available for only the City of St. Louis. These data allowed direct verification of the methodology used in calculating gasoline sales for the entire area. Gasoline sales were determined from the following data: (1) service station sales in each county and the City of St. Louis,[9, 10] (2) service station sales in the States of Missouri and Illinois,[9, 10] and (3) gasoline sales in gallons for the States of Missouri and Illinois.[11] Since the ratio of gasoline sales to the value of service station sales is relatively constant throughout a state, this ratio and the service station sales for each county were used to determine the gallonage sold.

The validity of this method was tested by comparing the results with those obtained for surrounding states, other urban areas in the country, and the City of St. Louis. The calculated and actual gasoline sales[12] for the City of St. Louis agreed within 6 percent. The annual per-capita gasoline consumption compared favorably with other metropolitan areas, being somewhat higher than cities with rapid transit facilities and slightly lower than others without these facilities.

The evaporation of gasoline from gas tanks and carburetors adds to the pollution arising from vehicular traffic and also reduces the quantity of gasoline available for combustion. An average of 1.5 percent by volume of the gasoline sales is assumed to approximate these evaporation losses.[13]

The gasoline consumption within each county and the City of St. Louis was estimated on the basis of gasoline sales in each area adjusted to reflect the inter-area travel. On the basis of traffic studies, employment data, and location of principal shopping areas, an estimated 20 percent of the gasoline sold in the Missouri counties and 10 percent sold in the Illinois counties are burned within the City of St. Louis. This is only a rough estimate and should be considered as such.

The consumption of diesel fuel may not be approximated in the same manner. The prime users of this fuel, the long-haul trucks, may purchase the fuel within the area, but use the majority of this fuel outside the area. By comparison with gasoline usage, the annual consumption of diesel fuel, and therefore the quantities of pollutants emitted, is minor. The errors introduced by the rough method of estimating diesel fuel consumption will therefore be small when considering the total emissions from transportation or mobile sources of pollution.

An estimate of diesel fuel consumption in the Study area was obtained by considering trucks and buses individually. The annual consumption of diesel fuel by buses was obtained from the local transit companies. For lack of more definitive information, national averages of diesel-powered vehicles in urban areas and their fuel consumption per mile were used to estimate the consumption of diesel fuel by trucks traveling in the area.[14]

Aircraft, Railroads, and Vessels - The emissions of pollutants from aircraft, railroads, and vessels were based on the following:

Aircraft - Number of flights originating or terminating in the area (Lambert Field).

Vessels - Quantity of fuels burned as determined by considering the number of vessels passing through the Study area and the average operating conditions.

Railroads - Quantity of fuels consumed in the area. These quantities were supplied by the individual railroad lines.

Results

Road Vehicles - An estimated 759 million gallons of gasoline, including gasoline for non-highway uses, is sold annually in the Study area. As shown in Table 18, gasoline sales in the City of St. Louis account for 43 percent and in the St. Louis County for 29 percent of the total Study area gasoline sales. A comparison of per-capita and per-vehicle use of gasoline in the Study area to those of the nation, surrounding states, and selected metropolitan areas is shown in Table 19.

Estimates of gasoline consumption in each of the political subdivisions in the Study area are given in Table 20. Approximately 9.5 billion vehicles miles is traveled annually in the Study area distributed among the political subdivisions according to the gasoline consumption data presented in Table 20.

The annual diesel fuel consumption in the Study area is approximately 12.5 million gallons, with 7 million gallons consumed by buses and the remaining 5.5 million gallons by diesel-powered trucks (Table 21).

The quantities of pollutants attributed to vehicular traffic are summarized in Table 22. More than 1 million tons of carbon monoxide, approximately 220,000 tons of hydrocarbons, and over 40,000 tons of oxides of nitrogen are contributed annually by the movement of vehicular traffic in the area. The contribution of diesel fuel is almost insignificant in comparison with that of gasoline.

Table 18. GASOLINE SALES FOR 1962 IN INTERSTATE AIR POLLUTION STUDY AREA

Jurisdiction	Retail service station sales, million dollars	Gasoline sales	
		Per capita, gal	Total, million gal
St. Charles County	6.5	470	24.9
St. Louis County	85.1	468	329.0
Jefferson County	7.1	414	27.5
City of St. Louis	56.7	294	220.0
Madison County	21.9	333	74.6
Monroe County	1.2	262	4.0
St. Clair County	23.7	306	80.0
Study Area	202.2	366	759.0

Table 19. COMPARISON OF STUDY AREA USE OF GASOLINE WITH SELECTED STATES AND CITIES

Jurisdiction	1960 population, millions	1962 gasoline consumption, million gallons	1962 vehicle registration	1962 persons per vehicle	Per capita use of gasoline, gallons	Per vehicle use of gasoline, gallons
United States	179.3	66,144	79,023,000	2.27	369	837
Missouri	4.3	1,804	1,698,000	2.53	417	1,060
Illinois	10.1	3,228	3,977,000	2.54	323	812
Indiana	4.7	1,865	2,174,000	2.16	400	860
Cincinnati	1.1	340	356,000	3.23	310	930
District of Columbia	0.8	217	217,000	3.52	286	1,000
Los Angeles County	6.8	2,701	3,450,000	1.97	390	783
Study area	2.1	759	780,000	2.66	366	975

Table 20. GASOLINE AND DIESEL FUEL CONSUMPTION IN STUDY AREA POLITICAL SUBDIVISIONS (million gallons/year)

Political subdivisions	Gasoline		Diesel consumption
	Consumption	Evaporation	
City of St. Louis	306.0	6.3	9.3
St. Louis County	257.7	5.3	1.9
St. Charles County	19.6	0.4	0.1
Jefferson County	21.6	0.4	0.1
Madison County	65.8	1.3	0.5
St. Clair County	70.6	1.4	0.6
Monroe County	3.5	0.1	n[a]
Total	744.8	15.2	12.5

[a]n = Negligible.

Table 21. GASOLINE AND DIESEL FUEL CONSUMPTION ROAD USE IN INTERSTATE AIR POLLUTION STUDY AREA, 1963 (million gallons/year)

Fuel and use	Quantity
Gasoline	
Road use	744
Evaporation	15
Diesel fuel	
Buses	7
Trucks	5.5

Table 22. AIR POLLUTANT EMISSIONS FROM TRANSPORTATION SOURCES IN INTERSTATE AIR POLLUTION STUDY AREA, 1963 (tons/year[a])

Source	Aldehydes	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Sulfur oxides	Particulates	B(a)P[a]
Road vehicles	1,560	1,083,000	231,000	43,400	3,600	4,700	456
Gasoline							
Exhaust	1,500	1,083,000	147,000	42,000	3,400	4,100	445
Blowby	n[b]	n[b]	48,000	n[b]	n[b]	n[b]	n[b]
Evaporation (tank and carburetor)	--	--	35,000	--	--	--	--
Diesel							
Exhaust	60	370	1,000	1,400	200	600	11
Aircraft	28	3,945	722	289	18	211	na[c]
Jet	17	230	50	110	15	190	na[c]
Turboprop	2	15	2	9	2	4	na[c]
Piston	9	3,700	670	170	1	17	na[c]
Railroad	140	800	2,500	3,000	500	1,500	24
Vessels	60	360	1,100	1,350	250	670	9
Totals	1,800	1,088,000	235,000	48,000	4,400	7,100	489

[a]Benzo(a) Pyrene in lb/year.
[b]n = Negligible.
[c]na = Information not available or not reported.

Aircraft, Railroads, and Vessels - In 1963 itinerant operations (flights that do not originate and terminate at St. Louis) totaled 226,748; local operations (flights that do originate and terminate at St. Louis) totaled 29,988.[15] An "operation" as used here means a takeoff and landing. A summary of air traffic activity by category is given in Table 23. Aircraft emissions at Lambert Field by aircraft type are given in Table 22. Emissions from aircraft activity in other parts of the survey area may be considered negligible.

Railroads consume about 27 million gallons of diesel fuel per year in the Study area.

Table 23. AIR TRAFFIC ACTIVITY AT LAMBERT FIELD, ST. LOUIS COUNTY, MISSOURI, FOR CALENDAR YEAR 1963

	Itinerant operations	Local operations
Air carrier	90,970	None
General aviation	119,085	22,977
Air Force and Army	12,681	5,470
Navy	4,012	1,541
Totals	226,748	29,988

Approximately 10,300 vessels, primarily diesel-powered tugs, pass through the Study area each year.[16] An estimated 13,000 gallons of fuel oil is consumed per month per mile of river. Emissions from vessels are also given in Table 22.

Collectively, aircraft, vessels, and railroads contribute extremely small amounts of pollutants to community-wide air pollution. The quantities are, however, considerable if considered in specified locations within the area.

INDUSTRIAL PROCESS EMISSIONS

The quantities of the different pollutants discharged from most industrial and some commercial establishments are attributable to two general types of operations, the pollutants generated by the combustion of fuels and the pollutants produced and discharged from the industrial processes. Unfortunately, emission factors are available for only a small number of processes and industries. In addition, quantities of pollutants discharged or the production data upon which to base emission estimates were not available in all cases. For example, data relating to the emission of benzo(a)pyrene from processes involving the treatment of hydrocarbon materials such as coal tars, asphalts, and petroleum were not reported. The industrial process emissions presented herein are therefore only a fraction of the area total.

In addition to the seven major pollutants included in this survey, other pollutants such as aluminum oxide, ammonia, chlorine, chlorinated cyanic acid, fluorides, hydrogen sulfide, hydrogen cyanide, ilmenite, magnesium oxide, nitric acid, phosphorous pentoxide, potassium meta bisulfite, potassium cyanide, sodium fluoride, sodium bifluoride, sodium hydroxide, zinc chloride, zinc oxide, and others are generated and released by the various industrial processes. The industrial process emissions of common pollutants that were obtained are summarized in Table 24. The geographical locations of the major industrial establishments are shown in Figures 6 and 7.

Methodology

Data relating to materials handled or processed and the types of processes employed were collected by the use of the industrial questionnaires and supplemented by personal contact with a number of industry groups. A detailed description of the sampling procedures, percentage of responses, and the treatment of data is included in the section on industrial fuel use.

Results

The St. Louis Metropolitan Area is a heavily industrialized complex. In 1963 almost 260,000 employees were employed by the area's industries. Almost all of the major types of industrial activity are present in the area. The most prevalent, in terms of employment, are the fabricated metals, primary metals, food and kindred products, and chemical products manufacturing industries. The types and quantities of pollutants discharged vary not only among the various industrial categories, but also within these categories.

Oil Refineries - Four large oil refineries are located within the boundaries of the Study area - three in the Alton-Wood River area and one in Monsanto, Illinois. The most important factors affecting refinery emissions are crude oil processing capacity,

Table 24. SUMMARY OF INDUSTRIAL PROCESS EMISSIONS IN INTERSTATE AIR POLLUTION STUDY AREA, 1963 (tons/year)

Pollutant and sources	Missouri				Illinois		Area total
	St. Louis City	St. Louis County	St. Charles County	Jefferson County	St. Clair County	Madison County	
Particulates							
Coffee processing	18	n[a]	0	0	2	18	38
Sulfuric acid manufacturing	0	77	0	0	115	0	192
Asphaltic concrete batching	28	94	0	0	7	69	198
Steel foundries	217	0	0	0	0	300	517
Gray iron foundries	265	0	0	0	158	14	437
Nonferrous foundries	32	1	3	0	4	1	41
Steel mills	0	0	0	0	0	11,438	11,438
Superphosphate manufacturing	0	57	0	0	166	0	223
Coke plants	9	0	0	0	0	64	73
Cement plants	0	3,600	0	0	0	0	3,600
Grain industry	1,907	0	0	0	3,813	975	6,695
Other sources reported on industrial questionnaire	188	6	50	8,000	2,435	3,384	14,063
Totals	2,664	3,835	53	8,000	6,700	16,263	37,515
Sulfur oxides							
Sulfuric acid manufacturing	0	8,663	0	0	11,118	0	19,781
Other sources reported on industrial questionnaire	na[b]	na[b]	na[b]	1,150	3,250	5,500	9,900
Totals	na[b]	8,663	na[b]	1,150	14,368	5,500	29,681
Nitrogen oxides							
Nitric acid manufacturing	0	0	0	2,475	0	0	2,475
Cement plants	0	1,387	0	0	0	0	1,387
Other sources reported on industrial questionnaire	5	na[b]	na[b]	na[b]	300	na[b]	305
Totals	5	1,387	na[b]	2,475	300	na[b]	4,167
Hydrocarbons							
Sources reported on industrial questionnaire	9,447	1	na[b]	800	1,500	na[b]	11,748

[a]n = Negligible, less than 0.5 ton/year.
[b]na = Information not available or not reported.

the processing techniques employed, level of maintenance and housekeeping, and the air pollution control measures used. Hydrocarbons, oxides of sulfur and nitrogen, carbon monoxide, and odors are the primary pollutants emitted from this operation. The reclamation of sulfur from various hydrocarbon streams containing hydrogen sulfide has resulted in approximately 95 percent reduction of sulfur dioxide emissions from two of the refineries. Previously these gas streams were used as boiler fuel. This use resulted in the conversion of hydrogen sulfide to sulfur dioxides and their subsequent release to the atmosphere. During 1963 none of the refineries had carbon monoxide boilers to burn the carbon monoxide in catalyst regenerator effluents; since then, however, one refinery has installed such a boiler. The hydrocarbon emissions from this source category have been included under solvent evaporation.

Cement Manufacturing - Two large cement plants, with a combined capacity of 7.6 million barrels per year, are located in the Study area. An estimated 3,600 tons of particulates and 1,400 tons of oxides of nitrogen are discharged annually from

the two plants. They are equipped with electrostatic precipitators and multiple cyclones. The overall collection efficiency is approximately 95 percent.

Asphaltic Concrete Manufacturing - Approximately 600,000 tons of rock is processed annually at the 14 asphaltic concrete plants in the area. Dust from the rotary drier and related handling operations is the principal pollutant. To minimize particulate emissions, 13 of the 14 plants in the area employ one or more primary dry cyclones followed by a wet scrubber. The remaining plant uses only a primary dry cyclone. Collectively, these plants emit an estimated 198 tons of particulates annually.

Steel Manufacturing - Two major steel plants are located in the Study area, one in Granite City and one in Alton, Illinois. One plant operates blast furnaces, open-hearth furnaces, and coke ovens; the other operates open-hearth furnaces and supplements its production with cupolas. The steel manufacturing industry emits an estimated 11,400 tons of particulates annually.

Foundries - Eight steel foundries, 18 gray-iron foundaries and 30 nonferrous foundries located in the Study area annually discharge approximately 517, 417, and 41 tons of particulates, respectively, to the atmosphere. Particulate emissions from eight electric arc furnaces are controlled by the use of cloth collectors, whereas ten are uncontrolled. Eleven open-hearth furnaces in steel foundries and 16 gray-iron cupolas are being operated without the use of any control equipment. Emissions from two cupolas are controlled by the use of wet cap scrubbers. Control equipment is not used to reduce the emissions from five electric induction furnaces; the emissions from these are, however, negligible if only the clean scrap is charged.

Grain Handling and Processing - St. Louis is a large grain handling and processing center. Grain processing plants are located in Granite City, Alton, Belleville, and the City of St. Louis. Grain storage facilities are scattered throughout the area. The particulate emissions from grain processing and handling, based on a loss factor of 0.3 percent of the grain handled, are estimated as 6,000 tons annually.

Coffee Roasting - Processing of approximately 32,000 tons of green coffee beans annually in the Study area results in a particulate emission of approximately 38 tons per year. In the indirect-fired roaster a portion of roaster gases is recirculated through the combustion area to reduce some of the smoke and odors. In the direct-fired roaster, however, all of the roaster gases are vented directly to the atmosphere. In addition to roasting, some particulate matter is also released from the stoners, coolers, cleaners, and handling systems.

Chemical Industry - The lack of emission factors and production data, and incomplete reporting of process emissions on industrial questionnaires made it impossible to estimate emissions from chemical industry operations in most cases. The manufacture of 950,000 tons of sulfuric acid by five firms in the area results in an estimated annual discharge of 20,000 tons of sulfur dioxide and 192 tons of sulfuric acid mist. Mist eliminators are used in all plants to reduce the acid mist emissions. Nitric acid manufacture causes an estimated emission of about 2,500 tons of nitrogen oxides per year. Superphosphate fertilizer manufacture results in emission of an estimated 225 tons of particulates per year.

Solvent Evaporation - Solvent usage in 1963 amounted to approximately 7 million gallons, or 21.5 pounds per capita per year. Table 25 lists solvent emissions in the Study area by consumer type. Solvents are used primarily in the application

Table 25. SOLVENT EMISSIONS IN INTERSTATE AIR POLLUTION STUDY AREA, 1963 (tons/year)

	St. Louis City	St. Louis County	St. Charles County	Jefferson County	Madison County	St. Clair County	Monroe County	Area total	Pounds/ capita/ year
1963 population[a]	711,000	781,000	65,000	77,000	234,000	264,000	15,000	2,147,000	--
Category									
Industrial	9,226	4,150	--	36	1,512	551	--	15,475	13.87
Dry cleaning	1,386	1,523	127	150	456	515	29	4,186	3.9
Nonindustrial	1,337	1,468	122	145	440	496	28	4,036	3.76
Totals	11,949	7,141	249	331	2,408	1,562	57	23,697	21.53

[a]Estimated by U.S. Bureau of Census.

of protective coatings, metal cleaning and degreasing, dry cleaning, and printing. Based on the assumption that 100 percent of the solvents used ultimately reach the atmosphere, total solvent emissions are approximately 24,000 tons per year, or approximately 7 percent of the hydrocarbons emitted in the Study area.

Evaporation of gasoline from stationary sources was also included in this category. Bulk storage tanks predominately have floating roofs, however, fixed-roof storage accounts for evaporation of over 7,000 tons per year. Other gasoline evaporation amounts to approximately 5,000 tons per year.

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APPENDIX - EMISSION FACTORS

The emission factors in this report were prepared after a thorough investigation of previous work by personnel of the Technical Assistance Branch, Division of Air Pollution. At the time of publication these factors are the best available for use in air pollution emission inventories. As technical advances are made in this area, these factors may in time become obsolete. Before these factors are used for other studies, careful attention should be paid to developments in the field to determine whether the emission factors have been up-dated.

Emission factors utilized in the Interstate Air Pollution Study are listed in Tables A-1 through A-17. The references cited are given at the end of the Appendix.

Table A-1. COMBUSTION OF COAL -- GASEOUS POLLUTANTS[a]
(pounds/ton of coal burned)

Pollutants	Power plants	Industrial	Domestic and commercial
Aldehydes (HCHO)	0.005	0.005	0.005
Carbon monoxide	0.5	3	50
Hydrocarbons (CH_4)	0.2	1	10
Nitrogen oxides as NO_2	20	20	8
Sulfur oxides as SO_2	38 S[b]	38 S[b]	38 S[b]

[a]Taken from Reference 1.
[b]S = % sulfur in coal.

Table A-2. COMBUSTION OF COAL -- EMISSIONS OF PARTICULATES AND BENZO(a)PYRENE

Type of unit	Particulate emission,[a] lb/ton of coal burned	B(a)P emission,[b] µg/ton of coal burned
Pulverized - general	16 A[c]	600
Dry bottom	17 A	
Wet bottom -		
Without reinjection	13 A	
With reinjection	24 A	
Cyclone	2 A	6,000[d]
Spreader stoker		700
Without reinjection	13 A	
With reinjection	20 A	
All other stoker	5 A	100,000
Hand-fired equipment	20	12,000,000

[a]Taken from Reference 1.
[b]Taken from Reference 2.
[c]A = % ash in coal.
[d]Taken from Reference 3.

Table A-3. COMBUSTION OF FUEL OIL[a]
(pounds/1,000 gallons of fuel oil burned)[b]

Pollutants	Large sources (1,000 hp or more)	Small sources (1,000 hp or less)
Aldehydes	0.6	2
Benzo(a)pyrene[c]	5,000 (μg/1,000 gal)	40,000 (μg/1,000 gal)
Carbon monoxide	0.04	2
Hydrocarbons	3.2	2
Nitrogen oxides as NO_2	104	72
Sulfur dioxide	157 S^d	157 S^d
Sulfur trioxide	2.4 S^d	2 S^d
Particulate	8	12

[a]Taken from Reference 4.
[b]Density of fuel oil equals 8 lb/gal, and 42 gal = 1 barrel.
[c]Taken from Reference 2.
[d]S = % sulfur in oil.

Table A-4. COMBUSTION OF NATURAL GAS[a]
(pounds/million cubic feet of gas burned)

Pollutants	Power plants	Industrial boilers	Domestic and commercial heating units
Aldehydes	1	2	n[b]
Benzo(a)pyrene[c]	na[d]	20,000 (μg/10^6 ft^3)	130,000 (μg/10^6 ft^3)
Carbon monoxide	n[b]	0.4	0.4
Hydrocarbons	n[b]	n[b]	n[b]
Nitrogen oxides	390	214	116
Sulfur oxides	0.4	0.4	0.4
Particulate	15	18	19

[a]Taken from Reference 5.
[b]n = Negligible.
[c]Taken from Reference 2.
[d]na = Not available.

Table A-5. INCINERATION OF REFUSE (pounds/ton of refuse burned)

Pollutants	Municipal[a] multiple chamber	Industrial and commercial		Domestic[c]	
				Single chamber	
		Single chamber	Multiple chamber	Without auxiliary gas burning	With auxiliary gas burning
Aldehydes	0.35	1.1	0.3	5.5	2
Benzo(a)pyrene	6,200 (μg/ton)	106,000 (μg/ton)	520,000 (μg/ton)	na[d]	na[d]
Carbon monoxide	0.3	4.3	0.5	300	na[d]
Hydrocarbons	0.3	0.45	0.25	100	1.5
Nitrogen oxides	2.4	1.6	2.0	7	2
Sulfur oxides	1.8	0.8	1.8	n[e]	n[e]
Particulate	9	25.0	4.0	39	6.3

[a]Taken from References 2, and 5 through 15.
[b]Taken from References 2 and 10.
[c]Taken from References 9-11, 13, and 14.
[d]na = Information not available.
[e]n = negligible.

Table A-6. OPEN BURNING OF REFUSE
(pounds/ton of refuse burned)

Pollutant	Burning dump[a]	Backyard burning[b]	Uncontrolled[c] automobile body burning
Aldehydes	4.0	3.6	
Benzo(a)pyrene	232,000 (μg/ton)	365,000 (μg/ton)	
Carbon monoxide	na[d]	na[d]	
Nitrogen oxides	0.6	1	
Sulfur oxides	1.2	0.8	
Hydrocarbons	280	280	
Particulate	47	47	10 lb/car

[a]Taken from References 5 and 13.
[b]Taken from References 5, 8, and 12-14.
[c]Taken from Reference 16.
[d]na = Not available.

Table A-7. AUTOMOTIVE AND DIESEL EXHAUST EMISSIONS
(pounds/1,000 gallons of fuel burned)

Pollutant	Gasoline engines[a, b] Exhaust	Diesel engines[c]
Aldehydes	4	10
Benzo(a)pyrene	0.27 (g/1,000 gal)[d]	0.4 (g/1,000 gal)[e]
Carbon monoxide	2,910	60
Hydrocarbons	524[f]	180
Nitrogen oxides	113	222[e]
Sulfur oxides	9	40
Particulates	11	110

[a]Includes blowby emissions, but not evaporation losses.
[b]Taken from Reference 17.
[c]Taken from Reference 18.
[d]Taken from Reference 19.
[e]Taken from Reference 20.
[f]Includes 128 lb/1,000 gal blowby emissions.

Table A-8. GASOLINE EVAPORATION EMISSION

Point of emission	lb/1,000 gal of throughput	Percent loss by volume
Storage tanks (refinery and bulk terminal)[b]		
Cone roof[c]	438	7.16
Floating roof[d]	73	1.19
25% cone roof, and 75% floating roof	164	2.68
Filling tank vehicles[e]		
Splash fill	8.2	0.14
Submerged fill	4.9	0
50% splash fill, and 50% submerged fill	6.4	0.11
Filling service station tanks[f]		
Splash fill	11.5	0.19
Submerged fill	7.3	0.12
50% splash fill,and 50% submerged fill	9.4	0.15
Filling automobile tanks[g]	116	0.19
Automobile evaporation losses (gas tank and carburetor)[h]	915	1.50

[a]An average gasoline specific gravity of 0.73 is assumed.
[b]Tank capacity basis.
[c]Taken from Reference 21.
[d]Taken from Reference 22.
[e]Taken from Reference 23.
[f]Taken from Reference 24.
[g]Taken from Reference 25.
[h]Taken from Reference 26.

Table A-9. PARTICULATE EMISSIONS FROM COFFEE PROCESSING
(pounds/1,000 pounds of green beans processed)

Process	Particulate emissions without cyclone[a]	Particulate emissions with cyclone[b]
Roaster		
Direct fired	3.8	1.1
Indirect fired	2.1	0.6
Stoner cooler cleaner and handling systems combined	0.7	0.2
Instant-coffee spray dryer	always controlled	0.7

[a]Taken from Reference 27.
[b]Taken from Reference 28.

Table A-10. EMISSIONS FROM PRODUCTION OF SUPERPHOSPHATE[a]

Den production	SiF_4 particulate emissions
28 tons/hr	490 lb/hr

[a]Taken from Reference 29.

Table A-11. FERROUS AND NONFERROUS EMISSIONS[a]

Process	Aerosol emission factor, lb/ton of raw material processed	
	Uncontrolled	Controlled
Gray-iron melting cupolas (avg)	14.7	0.26[b]
Electric steel melting furnaces (avg)	8.6	0.17[b]
Less than 5-ton capacity	10.6	-
5- to 20-ton capacity	5.7	-
50- to 75-ton capacity	9.6	-
Brass-bronze, crucible or open-flame furnace	3.5	-
Aluminum, magnesium		
Crucible, open-flame, or electric furnace	3.5	-
Reverberatory furnace	5.2	2.1[c]
Zinc	14.0	5.1[d]

[a]Taken from Reference 5.
[b]With baghouse control.
[c]With packed column scrubber and either baghouse or electrostatic precipitator as a secondary collector.
[d]Slag cover used as the only control method.

Table A-12. EMISSIONS FROM HOT ASPHALTIC CONCRETE PLANTS[a]

	Emissions of particulates, lb/ton of raw material processed
Uncontrolled (primary dry cyclone)	5
Controlled (wet scrubber)	0.45

[a]Taken from Reference 5.

Table A-13. EMISSION FACTORS FOR AIRCRAFT BELOW 3,500 FEET[a] (pounds/flight[b])

Pollutants	Jet aircraft	Turboprop aircraft		Piston-engine aircraft	
		2 engines	4 engines	2 engines	4 engines
Particulates	34	0.59	2.54	0.36	1.21
Carbon monoxide	40	2.02	8.71	73.5	245.0
Aldehydes	3.6	0.26	1.14	0.16	0.53
Hydrocarbons	9.1	0.27	1.18	14.72	49.1
Nitrogen oxides	19.5	1.13	4.86	4.41	14.7
Fuel consumption,[c] gal/flight	625	50	216	30	100

[a]Taken from Reference 30.
[b]A flight is the combination of a landing and a takeoff.
[c]Taken from Reference 31.

Table A-14. EMISSION FACTORS FOR SULFURIC ACID MANUFACTURE[a]

Pollutant	Emissions, lb/ton of acid produced
Sulfur dioxide	45
H_2SO_4 mist (with eliminator)	0.4

[a]Taken from References 14 and 32.

Table A-15. EMISSION FACTORS FOR NITRIC ACID PLANTS[a]

Pollutant	Emission rate
Oxides of nitrogen	55 lb/ton of acid produced
Particulates: (ammonium nitrate)	4% of ammonium nitrate production

[a]Taken from Reference 33.

Table A-16. EMISSION FACTORS FOR CEMENT MANUFACTURING PLANTS[a]

Type of process	Particulate emissions, lb/barrel of cement produced
Wet process (avg)	28
Dry process (avg)	45

[a]Taken from Reference 34.

Table A-17. EMISSIONS FROM STEEL MILLS[a]

Operation	Before control		Emission with control				Approximate volume of gases handled
	Stack loading, grains/scf	lb/ton of product	Control used[b]	Stack loading, grains/scf	lb/ton of product	Approximate efficiency, %	
Blast furnace	7-10	200	Preliminary cleaner (settling chamber or dry cyclone)[c]	3-6	-	60	87,000 scfm for a 1,000-ton per day furnace.
			Primary cleaner (wet scrubber)[c]	0.05-0.3-0.7[d]	5.4	90	
			Secondary cleaner (E.S.P. or V.S.)[c]	0.004-0.008	0.1-1.4	90	
Sintering machine	0.5-3.0	5-20-100	Dry cyclone	0.2-0.6	2.0	90	120,000-160,000 scfm for a 1,000-ton per day machine.
			E.S.P. (in series with dry cyclone)	0.01-0.05	1.0	95	
Sinter machine discharge-crusher, screener, and cooler	6.0	22	Dry cyclone	0.4	1.5	93	17,500 scfm for a 1,000-ton per day machine.
Open hearth (Not oxygen lanced)	0.1-0.4-2.0	1.5-7.5-20.0	E.S.P.	0.01-0.05	0.15	98	35,000 scfm for a 175-ton furnace.
			V.S.	0.01-0.06	0.15-1.1	85-98	
			Baghouse	0.01	0.07	99	
Open hearth (With oxygen lance)	0.1-0.6-2.5	9.3	E.S.P.	0.01-0.05	0.2	98	35,000 scfm for a 175-ton furnace.
			V.S.	0.01-0.06	0.2-1.4	85-98	
Electric arc furance	0.1-0.4-6.0	4.5-10.6-37.8	High efficiency scrubber	0.01	0.2	Up to 98	Highly variable depending on type of hood. May be about 30,000 scfm for a 50-ton furnace.
			E.S.P.	0.01-0.04	0.3-0.8	92-97	
			Baghouse	0.01	0.1-0.2	98-99	
Bessemer converter	0.8 - > 10	15-17-44	No practical method of control	-	-	-	-
Basic oxygen furnace	5-8	20-40-60	V.S.	0.03-0.12	0.4	99	Varies with amount of oxygen blown.
			E.S.P.	0.05	0.4	99	20 to 25 scfm per cfm of oxygen blown.
Scarfing machine	0.2-0.8	3 lb/ton of steel processed	Settling chamber	No data	No data	No data	85,000 scfm for a 45-inch, four-side machine.
Coke ovens (By-product type)	No data	0.1% of coal processed (rough estimate)	Emissions can be minimized through equipment design and operational techniques	No data	No data	No data	No data

[a]Taken from Reference 20.
[b]V.S. means venturi scrubber. E.S.P. means electrostatic precipitator.
[c]Used in series. Data on that basis.
[d]When three values are given, such as 5-20-100, the center value is the approximate average and values at either end are the lowest and highest values reported. All data are highly variable depending on nature of a specific piece of equipment, materials being processed, and operating procedure.

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